เอกสารอ้างอิง

1. Lamarsh, J. R., Introduction to Nuclear Reactor Theory, Addison-Wesley Publishing Company, Inc., Reading Massachusetts, 1975.
2. U.S. Atomic Energy Commission AECD-3645, "The Reactor Handbook," U.S. Atomic Energy Commission, n.p., 1955.
3. Ram K. S., Basic Nuclear Engineering, John Wiley and Sons, Inc., 1977.
4. Onega, R. J., An Introduction to Fission Reactor Theory, Physical Biological Sciences Ltd., Virginia, 1975.
5. Spiegel, M. R., Advanced Mathematics for Engineers and Scientists, Schaum's Outline Series, McGraw-Hill International Book Company, Singapore, 1983.
6. Saxena, H. C., Finite Differences and Numerical Analysis, S. Chand and Company Ltd., New Delhi, 8th ed., 1982.
7. Duderstadt, J. J., and L. J. Hamilton, Nuclear Reactor Analysis, John Wiley and Sons, Inc., 1976.
8. International Atomic Energy Agency Research Contract No. 2841/RB, "The VPI Program Package," Institute of Atomic Energy, Poland, 1984.

ภาคผนวก

ภาคผนวก ก

ก-1 เมทริกซ์และปัญหาค่าไอเกน

ในการลดรูปสมการดิฟเฟอเรนเชียลแบบปกติหรือแบบย่อย (ordinary or partial differential equation) ไปเป็นระบบสมการพีชคณิตเชิงเส้น จำนวนจุดเมชจะแปรผันกับจำนวนของสมการ ยิ่งเซตของสมการโตมากเท่าไรก็จะได้ความถูกต้องยิ่งขึ้น ระบบสมการที่กำลังศึกษาเพื่อหาค่าฟลักซ์และค่าคงที่มัลติพลิเคชัน คือ

$$\underline{\underline{A}}\,\underline{\Phi} = \frac{\underline{\underline{F}}\,\underline{\Phi}}{K} \qquad (ก.1)$$

$\underline{\underline{A}}$ เป็น เมทริกซ์จัตุรัส $\underline{\Phi}$ เป็น คอลัมน์เวกเตอร์ Φ_j เป็น ฟลักซ์ที่จุดเมช j

การหาค่าไอเกนใช้วิธี ซอร์สไอเทอเรชัน (source iteration or power method) ค่าฟลักซ์ Φ_j หาจากสมการ

$$\underline{\underline{A}}\,\underline{\Phi} = \underline{S} \qquad (ก.2)$$

เมื่อ S เป็น ซอร์สคอลัมน์เวกเตอร์ (source column vector) แทนแหล่งกำเนิดของนิวตรอน โดย S_j เป็นแหล่งกำเนิดที่ j

$$\underline{S} = \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_{N-1} \\ S_N \end{bmatrix} \qquad (ก.3)$$

$$S_j = \frac{F_j}{k}\,\Phi_j \qquad (ก.4)$$

ถ้าทราบค่าฟลักซ์นิวตรอน ก็สามารถคำนวณค่า $\underline{S}$ ได้ จากสมการ (ก.4) แต่เนื่องจากไม่ทราบทั้งค่าฟลักซ์และ k ดังนั้น ขั้นตอนต่อไปคือ การเดาค่า $\underline{S}$ แล้วคำนวณค่าฟลักซ์จากสมการ (ก.2) ในการหาคำตอบของสมการ (ก.2) จะต้องหาส่วนกลับของ A (inverse of A)

$$\underline{\underline{A}}^{-1}\underline{\underline{A}} = \underline{\underline{I}}$$

โดยที่ $\underline{\underline{I}}$ เป็นเมทริกซ์หนึ่งหน่วย คูณตลอดสมการ (ก.2) ด้วย $\underline{\underline{A}}^{-1}$ จะได้

$$\underline{\Phi} = \underline{\underline{A}}^{-1}\underline{S} \qquad (ก.5)$$

ซึ่งสามารถหาค่าฟลักซ์ได้ มีปัญหาที่มักจะพบบ่อย ๆ คือ

(1) บ่อยครั้งที่ $\underline{\underline{A}}$ มีขนาดใหญ่มาก ทำให้ยุ่งยากในการหา $\underline{\underline{A}}^{-1}$ จึงเลือกใช้วิธี การประมาณ

(2) เวกเตอร์ $\underline{S}$ เป็นตัวที่ไม่ทราบค่า เนื่องจากจริง ๆ แล้ว $\underline{S}$ ต้องหาโดยตรงจาก $\underline{\Phi}$ วิธีที่นิยมใช้กันในการหาค่าฟลักซ์และค่า $\underline{S}$ คือ วิธีเพาเวอร์ไอเทอเรชัน (power iteration method) ซึ่งมีลำดับขั้นคือ เริ่มต้นโดยการเดาค่าฟลักซ์ตัวแรก $\underline{\Phi}^{(0)}$ แล้ว คำนวณค่า $\underline{S}^{(0)}$ แล้วใช้สมการ (ก.5) คำนวณค่าฟลักซ์ตัวใหม่ $\underline{\Phi}^{(1)}$ โดย $\underline{\Phi}^{(1)}=\underline{\underline{A}}^{-1}\underline{S}^{(0)}$ ถ้าการไอเทอเรชันเป็นการหาค่า $\underline{\Phi}^{(1)}$ กระบวนการช่วงนี้จะเรียกว่า อินเนอร์ไอเทอเรชัน (inner iteration) จากค่า $\underline{\Phi}^{(1)}$ คำนวณค่าเดาที่ปรับปรุงใหม่คือ $\underline{S}^{(1)}$ แล้วทำต่อเนื่องไปโดยใช้

$$\underline{\Phi}^{(n+1)} = \underline{\underline{A}}^{-1}\underline{S}^{(n)} \qquad (ก.6)$$

เมื่อค่า $\underline{S}^{n}$ มีค่าใกล้ค่า $\underline{S}^{n+1}$ เพียงพอ ก็จะหยุดการคำนวณ กระบวนการทำซ้ำที่กำหนดจากสมการ (ก.6) เรียกว่า เอาท์เตอร์ไอเทอเรชัน (outer iteration)

โดยทั่วไปเมทริกซ์ที่ใช้มีขนาดใหญ่มากอาจถึงลำดับ 100 หรือมากกว่า แต่สมาชิกส่วนใหญ่ของเมทริกซ์จะเป็นศูนย์ สำหรับเมทริกซ์ A ขนาดเล็กสามารถใช้วิธีการแปลงโดยตรง แต่ถ้าเมทริกซ์ใหญ่มากมักนิยมใช้เทคนิคไอเทอเรชัน เนื่องจากมีข้อจำกัดทางจำนวนหน่วยความจำในเครื่องคอมพิวเตอร์

พิจารณา เมทริกซ์ A เป็นชนิดจัตุรัส มีสมาชิก a_{ij} เขียนแทนด้วย

$$\underline{\underline{A}} = (a_{ij}) = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1N} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & & & & \\ a_{N1} & a_{N2} & a_{N3} & \cdots & a_{NN} \end{bmatrix}$$

N เป็นลำดับของเมทริกซ์ ถ้า N ไม่เกิน 100 จะใช้วิธีเกาส์อิลิมิเนชัน (Gauss elimination) หาคำตอบของสมการ (ก.6)

พิจารณาจาก ความสัมพันธ์

$$\underline{\underline{A}}\underline{\Phi} = \underline{S} \qquad (ก.7)$$

วิธีการโดยตรงที่จะใช้หาคำตอบของสมการนี้คือ วิธีของโทมัส (Thomas algorithm) ซึ่งใช้ได้เฉพาะเมื่อเมทริกซ์ $\underline{\underline{A}}$ เป็นไตรไดอะโกแนล (tridiagonal) เท่านั้น คือ

$$\underline{\underline{A}} = \begin{bmatrix} a_1 & c_1 & 0 & \cdots & 0 \\ b_2 & a_2 & c_2 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & \cdots & b_{N-1} & a_{N-1} & c_{N-1} \\ 0 & \cdots & 0 & b_N & a_N \end{bmatrix} \qquad (ก.8)$$

ดังนั้น $a_{ij} = 0$ ถ้า $|i-j| > 1$ นอกจากนี้ยังได้กำหนดอีกว่า เมทริกซ์ $\underline{\underline{A}}$ เป็น diagonally dominant นั่นคือ

$$|a_i| > |c_i| \quad , \quad |a_i| \geq |b_i| + |c_i|$$

และ $$|a_N| > |b_N| > 0$$

ตามวิธีของโทมัส โดยการกำหนดให้เมทริกซ์ $\underline{\underline{A}}$ เขียนอยู่ในรูป factored form $\underline{\underline{A}} = \underline{\underline{H}}\underline{\underline{K}}$ เมื่อ

$$\underline{\underline{H}} = \begin{bmatrix} \alpha_1 & 0 \cdots 0 & 0 \\ b_2 & \alpha_2 & 0 \\ \vdots & & \\ 0 & b_N & \alpha_N \end{bmatrix} \quad , \quad \underline{\underline{K}} = \begin{bmatrix} 1 & \gamma_1 & 0 \cdots 0 & 0 \\ 0 & 1 & \gamma_2 & 0 \\ \vdots & & & \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

ทำการคูณสองเมทริกซ์นี้เข้าด้วยกัน แล้วเปรียบเทียบสมาชิกกับสมาชิกของสมการ (ก.8) จะได้

$$\alpha_1 = a_1 \quad \text{และ} \quad \gamma_1 = c_1/\alpha_1$$

$$\alpha_i = a_i - b\gamma_{i-1} \quad , \quad i=1,2,\ldots,N \qquad (ก.9)$$

และ $$\gamma_i = c_i/\alpha_i \quad , \quad i=2,3,4,\ldots,N$$

เพื่อหาค่า Φ_i ในเทอมของ S_i และสัมประสิทธิ์ a_i, b_i และ c_i พิจารณาคำตอบสำหรับ $\underline{g}$ เมื่อ

$$\underline{\underline{H}}\,\underline{g} = \underline{S} \qquad (ก.10)$$

$$\begin{bmatrix} \alpha_1 & 0 & 0 & \cdots & \\ b_2 & \alpha_2 & 0 & \cdots & \\ \vdots & & & & \\ 0 & & & b_N & \alpha_N \end{bmatrix} \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_N \end{bmatrix} = \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_N \end{bmatrix}$$

จะได้ $$g_1 = S_1/\alpha_1 \qquad (ก.11)$$

และ $$g_i = (S_i - b_i g_{i-1})/\alpha_i \quad , \quad i = 2,3,\ldots,N \qquad (ก.12)$$

คำนวณค่าฟลักซ์ จากสมการ

$$\underline{\underline{K}}\underline{\Phi} = \underline{g} = \underline{\underline{H}}^{-1}\underline{S}$$

$$\begin{bmatrix} 1 & \gamma_1 & 0 & 0 & \cdots & \\ 0 & 1 & \gamma_2 & 0 & \cdots & \\ 0 & 0 & 1 & \gamma_3 & & \\ \vdots & & & & 1 & \gamma_{N-1} \\ & & & & 0 & 1 \end{bmatrix} \begin{bmatrix} \Phi_1 \\ \Phi_2 \\ \vdots \\ \Phi_{N-1} \\ \Phi_N \end{bmatrix} = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_{N-1} \\ g_N \end{bmatrix}$$

หลังจากสิ้นสุดวิธีของโทมัส จะได้

$$\Phi_N = g_N = (S_N - b_N g_{N-1})/\alpha_N \qquad (ก.13)$$

และ $$\Phi_j = g_j - \gamma_j \Phi_{j-1} \quad , \quad j=N-1,N-2,\ldots,3,2,1 \qquad (ก.14)$$

ก-2 <u>เอาท์เตอร์ไอเทอเรชันโดยวิธีเพาเวอร์</u>

ปัญหาในการหาคำตอบของสมการการแพร่กระจายของนิวตรอน คือ ไม่ทราบค่าเทอมของแหล่งกำเนิด (source term) ซึ่งสัมพันธ์กับฟลักซ์ สมการที่จะหาคำตอบ คือ

$$\underline{\underline{A}}\ \underline{\Phi} = 1/k\ \underline{\underline{F}}\ \underline{\Phi} \qquad (ก.15)$$

$\underline{\underline{F}}$ เป็นเมทริกซ์ไดอะโกแนล

เอาเตอร์ไอเทอเรชัน เป็นวิธีที่ใช้ในการหาค่าไอเกน (k) สำหรับวิธีเพาเวอร์เป็นเทคนิคการ

ไอเทอเรชันแบบหนึ่งที่ใช้ในการหาค่า k ซึ่งเท่ากับค่ามัลติพลิเคชันแฟกเตอร์เมื่อ k เป็นค่าไอเกนที่ใหญ่ที่สุด ค่ามัลติพลิเคชันแฟกเตอร์เป็นอัตราส่วนระหว่างสองซอร์สไอเทอเรชันที่ต่อเนื่องกัน หรืออัตราส่วนระหว่างฟลักซ์ที่เวลา "P" กับฟลักซ์ที่เวลา "(P-1)" สำหรับขั้นตอนของการไอเทอเรชัน เริ่มจากการกำหนดเวกเตอร์หนึ่งขึ้นมา คือ

$$\underline{\Psi} = 1/k \; \underline{\underline{F}} \; \underline{\Phi} = 1/k \; \underline{S} \qquad \text{(ก.15)}$$

เมื่อ

$$\underline{S} = \underline{\underline{F}}\underline{\Phi} \qquad \text{(ก.16)}$$

$\underline{S}$ เป็น ซอร์สเวกเตอร์ การไอเทอเรชันกำหนดด้วยความสัมพันธ์

$$\underline{\underline{A}} \; \underline{\Phi}^{(P)} = \underline{\Psi}^{(P-1)} \qquad \text{(ก.17)}$$

จากสมการ (ก.16) จะได้

$$\underline{S}^{(P)} = \underline{\underline{F}} \; \underline{\Phi}^{(P)} \qquad \text{(ก.18)}$$

ค่าไอเกน คำนวณได้จากสมการ (ก.15) จากไอเทอเรชันครั้งที่ P จะได้

$$1/k^{(P)} \; \underline{S}^{(P)} = \underline{\Psi}^{(P-1)} \qquad \text{(ก.19)}$$

เมื่อคูณด้วยเทอม $\underline{S}^{(P)T}$ จะได้

$$k^{(P)} = \frac{\underline{S}^{(P)T} \cdot \underline{S}^{(P)}}{\underline{S}^{(P)T} \cdot \underline{\Psi}^{(P-1)}} \qquad \text{(ก.20)}$$

สรุปขั้นตอนต่าง ๆ ในการคำนวณ มีดังต่อไปนี้

(1) เดาค่าเริ่มต้น $\underline{\Phi}^{(0)}$ และ $k^{(0)}$

(2) ใช้สมการ (ก.18) คำนวณ ซอร์สเวกเตอร์

$$\underline{S}^{(0)} = \underline{\underline{F}} \; \underline{\Phi}^{(0)}$$

และ

$$\underline{\Psi}^{(0)} = 1/k^{(0)} \; \underline{S}^{(0)}$$

(3) หาค่าฟลักซ์ตัวใหม่ $\underline{\Phi}^{(1)}$ โดยใช้สมการ (ก.17)

$$\underline{\Phi}^{(1)} = \underline{\underline{A}}^{-1} \; \underline{\Psi}^{(0)}$$

ขั้นตอนนี้เป็นตอนที่ยากที่สุดเรียกว่า อินเนอร์ไอเทอเรชันและใช้วิธีของโทมัสหาคำตอบ สำหรับในอินเนอร์

ไอเทอเรชัน ปกติจะใช้เทคนิค successive over-relaxation หรือ เทคนิคการทำซ้ำอื่น ๆ ในกรณีศึกษาปัญหาการแพร่กระจายของนิวตรอนหลายกลุ่มหลายมิติ ส่วนในปัญหาแบบหนึ่งมิตินี้ มักจะใช้วิธีเกาส์เซียนอิลิมิเนชัน และไม่มีความจำเป็นต้องทำอินเนอร์ไอเทอเรชัน

(4) คำนวณซอร์สเวกเตอร์ $\underline{S}^{(1)}$ จาก สมการ (ก.18)

$$\underline{S}^{(1)} = \underline{\underline{F}}\ \underline{\Phi}^{(1)}$$

(5) คำนวณค่าไอเกน $k^{(1)}$ โดยใช้สมการ (ก.20)

$$k^{(1)} = \frac{\underline{S}^{(1)T} \cdot \underline{S}^{(1)}}{\underline{S}^{(1)T} \cdot \underline{\Psi}^{(0)}}$$

(6) คำนวณค่าใหม่ของ $\underline{\Psi}$ โดยใช้ สมการ (ก.15)

$$\underline{\Psi}^{(1)} = 1/k^{(1)}\ \underline{S}^{(1)}$$

(7) ทำซ้ำตั้งแต่ขั้นตอนที่ 3 ถึง 6 จนกระทั่งลู่เข้า (converge) ได้คำตอบ $k^{(P)}$ โดยที่

$$\left| \frac{k^{(P)} - k^{(P-1)}}{k^{(P)}} \right| < \epsilon$$

เมื่อค่า ϵ เป็นตัวเลขน้อย ๆ ขั้นตอนทั้งหมดนี้เป็นกระบวนการที่เรียกว่าเอาเตอร์ไอเทอเรชัน การลู่เข้าของกระบวนการนี้ สามารถแสดงให้เห็นได้ โดยเริ่มจากสมการ (ก.15) หาค่าฟลักซ์ โดย

$$\underline{\Phi} = k\ \underline{\underline{F}}^{-1}\ \underline{\Psi} \qquad \text{(ก.21)}$$

แทนสมการนี้ลงในสมการ (ก.14)

$$k\ \underline{\Psi} = \underline{\underline{F}}\ \underline{\underline{A}}^{-1} \underline{\Psi} \equiv \underline{\underline{B}}_s\ \underline{\Psi} \qquad \text{(ก.22)}$$

เมื่อ $\underline{\underline{B}}_s$ เป็นซอร์สไอเทอเรชันเมทริกซ์ โดย

$$\underline{\underline{B}}_s = \underline{\underline{F}}\ \underline{\underline{A}}^{-1} \qquad \text{(ก.23)}$$

ในที่สุด จะได้ว่า

$$k^{(P)}\ \underline{\psi}^{(P)} = \underline{\underline{B}}_s\ \underline{\psi}^{(P-1)} \qquad \text{(ก.24)}$$

เมื่อเทียบสมการ (ก.22) กับสมการ (ก.17) ต่อไปทำการกระจายเวกเตอร์ $\underline{\psi}^{(0)}$ ในเทอมของไอเกนเวกเตอร์ $\underline{e}_m$ ของ $\underline{\underline{B}}_s$ โดยให้ k_m เป็นค่าไอเกน ที่สอดคล้องกับ $\underline{e}_m$

$$\underline{\underline{B}}_s\ \underline{e}_m = k_m\ \underline{e}_m \qquad \text{(ก.25)}$$

ดังนั้น

$$\underline{\psi}^{(0)} = \sum_{m=1}^{n} a_m\ \underline{e}_m \qquad \text{(ก.26)}$$

สมการ (ก.24) เปลี่ยนเป็น

$$k^{(1)}\ \underline{\psi}^{(1)} = \underline{\underline{B}}_s\ \underline{\psi}^{(0)} = \sum_{m=1}^{n} a_m\ \underline{\underline{B}}_s\ \underline{e}_m$$

$$= \sum_{m=1}^{n} a_m\ k_m\ \underline{e}_m \qquad \text{(ก.27)}$$

ในทำนองเดียวกัน ถ้าทำกระบวนการนี้ต่อไป จะได้

$$\underline{\psi}^{(P)} = \frac{1}{\prod_{i=1}^{P} k^{(i)}} \sum_{m=1}^{n} a_m\ k_m^{P}\ \underline{e}_m \qquad \text{(ก.28)}$$

$$= k_1^{(P)} \left[\frac{a_1}{\prod_{i=1}^{P} k^{(i)}}\ \underline{e}_1 + \sum_{m=2}^{n} \frac{a_m}{\prod_{i=1}^{P} k^{(i)}} \cdot \left[\frac{k_m}{k_1}\right]^{P}\ \underline{e}_m \right]$$

เมื่อค่า P โตมาก และถ้ากำหนดให้ $k_1 > k_2 > k_3 > \ldots > k_n$

จะได้ว่าเทอมผลรวม (summation) กลายเป็นศูนย์ ดังนั้น

$$\underline{\Psi}^{(p)} \simeq k_1^{(p)} \underline{e}_1 \qquad \text{(ก.29)}$$

ภาคผนวก ข

ข-1 รายละเอียดโปรแกรม MAINMENU.BAS

```
10   REM MAIN MENU
12   COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
13   COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
15   P$="PROGRAM ":S1$="[1] INTRODUCTION ":S2$="[2] INPUT PREPARATION " :S3$=
     "[3] RUN ":S4$="[4] PRINT OUTPUT ON SCREEN ":S5$="[5] PRINT OUTPUT
     ON PRINTER "
16   S6$="[6] EXIT TO MAIN MENU ":S7$="SELECTED NUMBER-->" :FIL3$="SUBMENU.BAS"
     : MAI$="MAINMENU.BAS" :DX1$="READTX1.BAS":DX2$="READTX2.BAS"
20   CLS : LOCATE 1,30:PRINT"NUCLEAR TECHNOLOGY"   : LOCATE 2,27:PRINT
     "CHULALONGKORN UNIVERSITY"
21   FOR I=4 TO 14 : LOCATE I,1  : PRINT CHR$(219):LOCATE I,80:PRINT
     CHR$(219):NEXT I
30   LOCATE 4,2  : PRINT STRING$(78,CHR$(223))
40   LOCATE 5,1   : PRINT CHR$(219)  : LOCATE 5,30  : PRINT"MAIN MENU"
50   LOCATE 6,15  : PRINT"[1] CALCULATION OF FAST GROUP CONSTANTS."
60   LOCATE 7,15  : PRINT"[2] CALCULATION OF THERMAL GROUP CONSTANTS."
70   LOCATE 8,15  : PRINT"[3] CALCULATION OF THERMAL DISADVANTAGE FACTORS."
80   LOCATE 9,15  : PRINT"[4] SOLUTION OF 1-D 1-G DIFFUSION EQUATION."
90   LOCATE 10,15  : PRINT"[5] SOLUTION OF 1-D 3-G DIFFUSION EQUATION."
100  LOCATE 11,15 :PRINT"[6] CALCULATION OF BURNUP."
110  LOCATE 12,15 :PRINT"[7] EXIT"
120  LOCATE 14,2  :PRINT STRING$(78,CHR$(220))
130  LOCATE 16,30 :PRINT "SELECTED NUMBER-->":LOCATE 16,48:PRINT CHR$(219)
140  A$=INPUT$(1) : LOCATE 16,48  : PRINT A$
150  IF ASC(A$)<49 OR ASC(A$)>55 THEN BEEP  : GOTO 130
160  ON VAL(A$) GOTO 200,400,600,800,1000,1200,1400
200  FIL1$="FARCON.TXT" :FIL2$="C:FARCON.OUT" : P1$="FARCON "
203  IP$="INPUT1.BAS" : SHEL$="B:FARCON.EXE" : COP$="COPY C:FARCON.OUT
     LPT1: > C:A"
206  TIT$="PROGRAM CALCULATES FAST SPECTRUM AND FAST GROUP CONSTANTS"
210  CHAIN FIL3$
400  FIL1$="SLOCON.TXT" :FIL2$="C:SLOCON.OUT" :P1$="SLOCON "
403  IP$="INPUT2.BAS" : SHEL$="B:SLOCON.EXE" : COP$="COPY C:SLOCON.OUT
     LPT1: > C:A"
405  TIT$="PROGRAM CALCULATES THERMAL SPECTRUM AND THERMAL GROUP CONSTANTS"
410  CHAIN FIL3$
600  FIL1$="DISFAC.TXT" :FIL2$="C:DISFAC.OUT" :P1$="DISFAC "
603  IP$="INPUT3.BAS" : SHEL$="B:DISFAC.EXE" : COP$="COPY C:DISFAC.OUT
```

```
    LPT1: > C:A"
605 TIT$="       PROGRAM CALCULATES THERMAL DISADVANTAGE FACTORS"
610 CHAIN FIL3$
800 FIL1$="ODOG.TXT" :FIL2$="C:ODOG.OUT" : P1$="ODOG "
803 IP$="INPUT4.BAS" : SHEL$="B:ODOG.EXE" : COP$="COPY C:ODOG.OUT
    LPT1: > C:A"
805 TIT$="   PROGRAM CALCULATES SOLUTION OF 1-D 1-G DIFFUSION EQUATION"
810 CHAIN FIL3$
1000 FIL1$="ODMUG.TXT" :FIL2$="C:ODMUG.OUT" :P1$="ODMUG "
1003 IP$="INPUT5.BAS" : SHEL$="A:ODMUG.EXE" : COP$="COPY C:ODMUG.OUT
    LPT1: > C:A"
1005 TIT$="  PROGRAM CALCULATES SOLUTION OF 1-D 3-G DIFFUSION EQUATION"
1010 CHAIN FIL3$
1200 FIL1$="FBURN.TXT" :FIL2$="C:FBURN.OUT" :P1$="FBURN "
1203 IP$="INPUT6.BAS" : SHEL$="B:FBURN.EXE" : COP$="COPY C:FBURN.OUT
    LPT1: > C:A"
1205 TIT$="             PROGRAM FOR DEPLETION CALCULATION"
1210 CHAIN FIL3$
1400 SYSTEM
```

ข-2 รายละเอียดโปรแกรม SUBMENU.BAS

```
10   'SUBMENU
12   COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
13   COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
100  BEEP  : LU$=CHR$(218):RU$=CHR$(191):LD$=CHR$(192):RD$=CHR$(217)
    :V$=CHR$(179)
200  CLS : COLOR 7,0 : LOCATE 1,33  : PRINT P$;P1$
205  LOCATE 2,10:PRINT TIT$
210  FOR I=4 TO 14 : LOCATE I,1  : PRINT CHR$(219)  : LOCATE I,80:PRINT
    CHR$(219):NEXT I
220  LOCATE 4,2  : PRINT STRING$(78,CHR$(223))
230  LOCATE 5,1   : PRINT CHR$(219)  : LOCATE 5,30  : PRINT"     MENU  "
240  LOCATE 6,28  : PRINT S1$
250  LOCATE 7,28  : PRINT S2$
260  LOCATE 8,28  : PRINT S3$;P$;P1$
270  LOCATE 9,28  : PRINT S4$
280  LOCATE 10,28 :PRINT S5$
290  LOCATE 11,28 :PRINT S6$
300  LOCATE 14,2  :PRINT STRING$(78,CHR$(220))
310  LOCATE 16,30 :PRINT S7$  : LOCATE 16,48  : PRINT CHR$(219)
320  A$=INPUT$(1) : LOCATE 16,48  : PRINT A$
330  IF ASC(A$)<49 OR ASC(A$)>54 THEN BEEP : GOTO 310
335  ON VAL(A$) GOTO 340,350,360,370,380,390
```

```
340  CHAIN DX1$
350  CHAIN IP$
360  CLS : GOSUB 400 : SHELL SHEL$ : CHAIN FIL3$
370  CHAIN DX2$
380  BEEP : CLS: LOCATE 10,25:PRINT LU$;STRING$(27,196);RU$
381       LOCATE 11,25:PRINT V$;"     SWITCH ON PRINTER     ";V$
382       LOCATE 12,25:PRINT LD$;STRING$(27,196);RD$
383  LOCATE 22,25:PRINT "ESC to Exit   RETURN to print"
384  A$=INPUT$(1) :IF A$=CHR$(27) THEN CHAIN FIL3$
385  BEEP : CLS : LOCATE 23,65:COLOR 31,0:PRINT "Wait..."
386  SHELL COP$    : COLOR 7,0 : CHAIN FIL3$
390  CHAIN MAI$
400  CLS : REM PAINT "RUNNING"
401  C$=CHR$(219):U$=CHR$(223):D$=CHR$(220):B$=" "
402  LOCATE 10,24:PRINT C$;U$;U$;C$;B$;C$;B$;B$;C$;B$;C$;D$;B$;C$;B$;C$;
     D$;B$;C$;B$;C$;B$;C$;D$;B$;C$;B$;C$;U$;U$;U$
403  LOCATE 11,24:PRINT C$;U$;C$;U$;B$;C$;B$;B$;C$;B$;C$;U$;C$;C$;B$;C$;
     U$;C$;C$;B$;C$;B$;C$;U$;C$;C$;B$;C$;B$;U$;C$
404  LOCATE 12,24:PRINT U$;B$;B$;U$;B$;U$;U$;U$;U$;B$;U$;B$;B$;U$;B$;U$;
     B$;B$;U$;B$;U$;B$;U$;B$;B$;U$;B$;U$;U$;U$;U$
405  IF P1$="FARCON " THEN 415
406  IF P1$="SLOCON " THEN 450
407  IF P1$="DISFAC " THEN 490
408  IF P1$="ODOG " THEN 530
409  IF P1$="ODMUG " THEN 570
410  IF P1$="FBURN " THEN 610
415  ' PAINT FARCON
420  LOCATE 13,25:PRINT C$;U$;U$;U$;B$;C$;U$;U$;C$;B$;C$;U$;U$;C$;B$;C$;
     U$;U$;C$;B$;C$;U$;U$;C$;B$;C$;D$;B$;C$
430  LOCATE 14,25:PRINT C$;U$;U$;U$;B$;C$;U$;U$;C$;B$;C$;U$;C$;U$;B$;C$;
     B$;B$;D$;B$;C$;B$;B$;C$;B$;C$;U$;C$;C$
440  LOCATE 15,25:PRINT U$;B$;B$;B$;B$;U$;B$;B$;U$;B$;U$;B$;B$;U$;B$;U$;
     U$;U$;U$;B$;U$;U$;U$;U$;B$;U$;B$;B$;U$
445  GOTO 645
450  ' PAINT SLOCON
460  LOCATE 13,25:PRINT C$;U$;U$;U$;B$;C$;B$;B$;B$;B$;C$;U$;U$;C$;B$;C$;
     U$;U$;U$;B$;C$;U$;U$;C$;B$;C$;D$;B$;C$
470  LOCATE 14,25:PRINT U$;U$;U$;C$;B$;C$;B$;B$;B$;B$;C$;B$;B$;C$;B$;C$;
     B$;B$;B$;B$;C$;B$;B$;C$;B$;C$;U$;C$;C$
480  LOCATE 15,25:PRINT U$;U$;U$;U$;B$;U$;U$;U$;U$;B$;U$;U$;U$;U$;B$;U$;
     U$;U$;U$;B$;U$;U$;U$;U$;B$;U$;B$;B$;U$
485  GOTO 645
490  ' PAINT DISFAC
500  LOCATE 13,26:PRINT U$;C$;U$;U$;C$;B$;C$;B$;C$;U$;U$;U$;B$;C$;U$;U$;
     U$;B$;C$;U$;U$;C$;B$;C$;U$;U$;U$
```

```
510  LOCATE 14,26:PRINT B$;C$;B$;B$;C$;B$;C$;B$;U$;U$;U$;C$;B$;C$;U$;U$;
     U$;B$;C$;U$;U$;C$;B$;C$;B$;B$;B$
520  LOCATE 15,26:PRINT U$;U$;U$;U$;U$;B$;U$;B$;U$;U$;U$;U$;B$;U$;B$;B$;
     B$;B$;U$;B$;B$;U$;B$;U$;U$;U$;U$
525  GOTO 645
530 ' PAINT ODOG
540  LOCATE 13,29:PRINT C$;U$;U$;C$;B$;U$;C$;U$;U$;C$;B$;C$;U$;U$;C$;B$;
     C$;U$;U$;U$
550  LOCATE 14,29:PRINT C$;B$;B$;C$;B$;B$;C$;B$;B$;C$;B$;C$;B$;B$;C$;B$;
     C$;B$;U$;C$
560  LOCATE 15,29:PRINT U$;U$;U$;U$;B$;U$;U$;U$;U$;U$;B$;U$;U$;U$;U$;B$;
     U$;U$;U$;U$
565  GOTO 645
570 'PAINT ODMUG
580  LOCATE 13,26:PRINT C$;U$;U$;C$;B$;U$;C$;U$;U$;C$;B$;C$;U$;C$;U$;C$;
     B$;C$;B$;B$;C$;B$;C$;U$;U$;U$
590  LOCATE 14,26:PRINT C$;B$;B$;C$;B$;B$;C$;B$;B$;C$;B$;C$;B$;C$;B$;C$;
     B$;C$;B$;B$;C$;B$;C$;B$;U$;C$
600  LOCATE 15,26:PRINT U$;U$;U$;U$;B$;U$;U$;U$;U$;U$;B$;U$;B$;U$;B$;U$;
     B$;U$;U$;U$;U$;B$;U$;U$;U$;U$
605  GOTO 645
610 ' PAINT FBURN
620  LOCATE 13,27:PRINT C$;U$;U$;U$;B$;U$;C$;U$;U$;C$;B$;C$;B$;B$;C$;B$;
     C$;U$;U$;C$;B$;C$;D$;B$;C$
630  LOCATE 14,27:PRINT C$;U$;U$;U$;B$;B$;C$;U$;U$;C$;B$;C$;B$;B$;C$;B$;
     C$;U$;C$;U$;B$;C$;U$;C$;C$
640  LOCATE 15,27:PRINT U$;B$;B$;B$;B$;U$;U$;U$;U$;U$;B$;U$;U$;U$;U$;B$;
     U$;B$;B$;U$;B$;U$;B$;B$;U$
645  BEEP : RETURN
```

ข-3 รายละเอียดโปรแกรม READTX1.BAS

```
3    ON ERROR GOTO 210
5    COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7    COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
10   DIM A$(1000)
20   OPEN FIL1$ FOR INPUT AS #1
30   I=0
40   IF EOF(1) THEN N=I : GOTO 80
50   I=I+1
60   LINE INPUT #1,A$(I)
70   GOTO 40
80   A=1 : B=15
90    CLS  :  II=4
```

```
100  IF B>N THEN B=N : GOTO 110
110  FOR I=A TO B  : II=II+1
120  LOCATE II,1 : PRINT A$(I)
130  NEXT I
140  LOCATE 22,1 : PRINT STRING$(80,CHR$(22))
150  LOCATE 23,5 : PRINT "  (GREY)+ = NEXT PAGE     (GREY)- = PREVIOUS PAGE
     Return = EXIT"
160  B$=INPUT$(1)
170  IF B$=CHR$(13) THEN CLOSE :CHAIN FIL3$
180  IF B$=CHR$(43) THEN 250
190  IF B$=CHR$(45) THEN 260
200  BEEP : GOTO 160
210  CLOSE :BEEP:CLS:COLOR 0,7:PRINT "ERROR":COLOR 7,0: CHAIN FIL3$
250  IF B=N THEN 200 ELSE A=B :B=B+14 : GOTO 90
260  IF A=1 THEN 200 ELSE B=A : A=A-14 : GOTO 90
```

ข-4 รายละเอียดโปรแกรม READTX2.BAS

```
3    ON ERROR GOTO 210
5    COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7    COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
10   DIM A$(1000)
20   OPEN FIL2$ FOR INPUT AS #1
22   LOCATE 23,65:COLOR 31,0 : PRINT "Wait...":COLOR 7,0
30   I=0
40   IF EOF(1) THEN N=I : GOTO 80
50   I=I+1
60   LINE INPUT #1,A$(I)
70   GOTO 40
80   A=1 : B=15
90   CLS :  II=4
100  IF B>N THEN B=N : GOTO 110
110  FOR I=A TO B  : II=II+1
120  LOCATE II,1 : PRINT A$(I)
130  NEXT I
140  LOCATE 22,1 : PRINT STRING$(80,CHR$(22))
150  LOCATE 23,5 : PRINT "  (GREY)+ = NEXT PAGE     (GREY)- = PREVIOUS PAGE
     Return = EXIT"
160  B$=INPUT$(1)
170  IF B$=CHR$(13) THEN CLOSE : CHAIN FIL3$
180  IF B$=CHR$(43) THEN 250
190  IF B$=CHR$(45) THEN 260
200  BEEP : GOTO 160
210  BEEP :CLS:COLOR 0,7:PRINT "ERROR":COLOR 7,0 : CHAIN FIL3$
```

```
250  IF B=N THEN 200 ELSE A=B :B=B+14 : GOTO 90
260  IF A=1 THEN 200 ELSE B=A : A=A-14 : GOTO 90
```

ข-5 รายละเอียดโปรแกรม INPUT1.BAS

```
4    ON ERROR GOTO 3000
12   COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
13   COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
15   K$="HELP":KK$=CHR$(13)
20   KEY 1,K$+KK$
400  AA$="                                    Press ESC to Exit
450  CC$="   F1 for help   "  :CCC$="   RETURN if unchange"
500  CLS : ' INPUT PREPARATION
502  DIM IDD$(14) ,NU(14),BG(10),H$(20),P(40)
504  IDD$(1)="ZIRCALOY-2":IDD$(2)="HYDROGEN":IDD$(3)="OXYGEN":IDD$(4)=
     "BERILLIUM":IDD$(5)="BORON-10":IDD$(6)="CARBON":IDD$(7)=
     "STAINLESS STEEL-304"
506  IDD$(8)="URANIUM-235":IDD$(9)="URANIUM-236":IDD$(10)="URANIUM-238":
     IDD$(11)="PLUTONIUM-239":IDD$(12)="PLUTONIUM-240":IDD$(13)=
     "PLUTONIUM-241":IDD$(14)="PLUTONIUM-242"
510  BEEP :  LOCATE 2,30:PRINT  "INPUT PREPARATION"
511  LOCATE 5,5 :PRINT "Enter [1]enter new data [2]correct old data"
512  LOCATE 7,10:PRINT C$: LOCATE 7,10:INPUT "", INX$ :   CLS
513  IF INX$="2" THEN GOSUB 4000
514  LOCATE 5,5 :PRINT "     Enter title of your job. ( < 80 character )"
518  C$=NUM$ :GOSUB 3100  : IF X$<>"" THEN NUM$=X$
520  LOCATE 5,5 :PRINT "     Enter [1] if nuclear data library printed "
530  LOCATE 6,5 :PRINT "           [0] if nuclear data library not printed "
540  C$=STR$(F) : GOSUB 3100 : IF X$<>"" THEN F=VAL(X$)
550  LOCATE 5,5 :PRINT "     Enter [1] if 33 groups of res. escape prob.
     given in input"
560  LOCATE 6,5 :PRINT "           [0] if res. escape prob. for groups 1-32
     calculated by program"
570  GOSUB 3200 : C$=STR$(FF) : GOSUB 3100
575  IF   X$=K$ THEN GOSUB 1000 :CLS:BEEP:GOTO 550
577  IF X$="" THEN 600
580  FF=VAL(X$)
600  FOR I=1 TO 14  : CLS
610  LOCATE 5,5 :PRINT "     Enter number density (atom /barn-cm) of ";IDD$(I)
615  GOSUB 3200 : C$=STR$(NU(I)) :GOSUB 3100
617  IF   X$=K$ THEN  GOSUB 1097 :CLS :BEEP : GOTO 610
618  IF X$="" THEN 625
620  NU(I)=VAL(X$)
625  NEXT I
```

```
630  IF FF=1 THEN 870
640  LOCATE 5,5 :PRINT "     Enter fuel volume fraction in the cell"
650  C$=STR$(VA) : GOSUB 3100 : IF X$<>"" THEN VA=VAL(X$)
660  LOCATE 5,5 :PRINT "     Enter clad volume fraction in the cell"
670  C$=STR$(VC) : GOSUB 3100 : IF X$<>"" THEN VC=VAL(X$)
680  LOCATE 5,5 :PRINT "     Enter moderator volume fraction in the cell"
690  C$=STR$(VM) : GOSUB 3100 : IF X$<>"" THEN VM=VAL(X$)
700  LOCATE 5,5 :PRINT "     Enter fuel enrichment (fraction of U-235)"
710  C$=STR$(ENRICH) : GOSUB 3100 : IF X$<>"" THEN ENRICH=VAL(X$)
720  LOCATE 5,5 :PRINT "     Enter fuel surface temperature (K) "
730  C$=STR$(TS) : GOSUB 3100 : IF X$<>"" THEN TS=VAL(X$)
740  LOCATE 5,5 :PRINT "     Enter fuel element center temperature (K) "
750  C$=STR$(TC) : GOSUB 3100 : IF X$<>"" THEN TC=VAL(X$)
760  LOCATE 5,5 :PRINT "     Enter fuel element radius (cm) "
770  C$=STR$(R) : GOSUB 3100 : IF X$<>"" THEN R=VAL(X$)
780  LOCATE 5,5 :PRINT "     Enter type of cell geometry [1] hexagonal
     [0] square "
790  C$=STR$(Z) : GOSUB 3100 : IF X$<>"" THEN  Z=VAL(X$)
800  LOCATE 5,5 :PRINT "     Enter uranium dioxide density (gm/cm**3) "
810  C$=STR$(PUO2) : GOSUB 3100 : IF X$<>"" THEN  PUO2=VAL(X$)
820  'LOCATE 5,5 :PRINT "     Enter resonance integral "
830  'C$=STR$(RIS) : GOSUB 3100 : IF X$<>"" THEN  RIS=VAL(X$)
840  LOCATE 5,5 :PRINT "     Enter res. escape prob. for group 33  "
850  C$=STR$(P) : GOSUB 3100 : IF X$<>"" THEN  P=VAL(X$)
860  GOTO 875
870  FOR I=1 TO 33
872  LOCATE 5,5:PRINT "     Enter res. capture escape prob. for group # ";I
873  C$=STR$(P(I)) : GOSUB 3100 : IF X$<>"" THEN  P(I)=VAL(X$) : CLS
874  NEXT I
875  II=1
880  LOCATE 5,5 :PRINT "     Enter buckling value.  [Enter 999 for the
     last value] "
885  LOCATE 6,5 :PRINT "          the calculation will be repeated for each
     buckling value."
886  GOSUB 3200 :C$=STR$(BG(II)) : GOSUB 3100
887  IF X$=K$ THEN GOSUB 2100 :CLS :BEEP : GOTO 880
888  IF X$="" THEN 895
890  BG(II)=VAL(X$)
895  IF BG(II)<> 999 THEN II=II+1 :GOTO 880
900  NN=II
910  OPEN "FARCON.DAT" FOR OUTPUT AS #1
915  WRITE #1,NUM$
920  WRITE #1, F,FF
930  FOR I=1 TO 6 : PRINT #1,NU(I);",";  : NEXT  : PRINT #1,NU(7)
933  FOR I=8 TO 13: PRINT #1,NU(I);",";  : NEXT  : PRINT #1,NU(14)
```

```
935  IF FF=1 THEN 940
936  WRITE #1,VA,VC,VM,ENRICH,TS,TC,R,Z
937  WRITE #1,PUO2,RIS,P  :  GOTO 946
940  FOR I=1 TO 10:  PRINT #1,P(I);",";  :NEXT I:PRINT #1,P(11)
942  FOR I=12 TO 21: PRINT #1,P(I);",";  :NEXT I:PRINT #1,P(22)
943  FOR I=23 TO 32: PRINT #1,P(I);",";  :NEXT I:PRINT #1,P(33)
946 'WRITE #1,NN   '** WARNING **
950  FOR I=1 TO NN : PRINT #1,BG(I) : NEXT I
960  CLOSE #1 :  CHAIN FIL3$
1000 REM HELP FOR INPUT IFF VALUE
1005 H$(1)=STRING$(73," ")
1010 H$(2)="    It is recommended to choose this value = 0 if a fuel cell"
1020 H$(3)=" has to be calculated as there is no possibility to calculate"
1030 H$(4)=" resonance capture escape probabilities. For the same reason the "
1040 H$(5)=" probability for the last group, P(33), must be given as 1.0 if  "
1050 H$(6)=" no special information. In the case of a nonfissionable medium   "
1060 H$(7)=" e.g. water gap or reflector it is recommended to choose this "
1070 H$(8)=" value =1 and put all the P(i)=1.0. The absorption cross section"
1080 H$(9)=" for water  obtained on this way are always zero. "
1081 H$(10)=STRING$(73, " ") :LL=10 : GOSUB 2000
1096 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1096
1097 REM  HELP FOR INPUT NUMBER DENSITIES
1098 H$(1)=STRING$(73," ")
1100 H$(2)="      The number densities should be precalculated by the user  "
1105 H$(3)="    according to the basic formula "
1110 H$(4)="                                   "
1120 H$(5)="           N(i) = Na*Rho(i)*V(i)*Z(i)/Wt(i)  "
1130 H$(6)="                                   "
1140 H$(7)="where    Na -  Avogadro's number = 6.023E+23 nuclei/mole"
1150 H$(8)="     Rho(i) - mass dendity of isotope or material i in gm/cm**3"
1160 H$(9)="      Wt(i) - atomic mass of isotope or material i  "
1170 H$(10)="      V(i) - volume fraction of the isotope or material i  "
1180 H$(11)="      Z(i) - number of atoms of type i per molecule "
1181 H$(12)="    for example"
1182 H$(13)="       Hydrogen->  N(H)=Na*Rho(H2O)*V(H2O)*2/18"
1183 H$(14)="    where Z=2 atom of H in 1 molecule of water(H2O)"
1184 H$(15)="          Wt(H2O) = 18"
1185 H$(16)="       Uranium-->  N(U)=Na*Rho(UO2)*V(UO2)*1/270"
1186 H$(17)="    where Z=1 atom of U in 1 molecule of UO2"
1187 H$(18)="          Wt(UO2) = 270"
1188 H$(19)="    Oxygen-> N(O)=Na[Rho(H2O)*V(H2O)*1/18+Rho(UO2)*V(UO2)*2/270]"
1190 H$(20)=STRING$(73," ") : LL=20 :GOSUB 2000
1195 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1195
2000 CLS :  COLOR 0,7:PRINT STRING$(75," ")
2087 FOR IK=1 TO LL
```

```
2090 COLOR 0,7:PRINT" ";:COLOR 7,0:PRINT H$(IK);:COLOR 0,7:LOCATE IK+1,75:
     PRINT" ":COLOR 7,0
2092 NEXT IK
2095 COLOR 0,7:PRINT AA$ :COLOR 7,0  :RETURN
2100 REM HELP FOR INPUT IFF VALUE
2110 H$(1)=STRING$(73," ")
2111 H$(2)="          The buckling value may be estimated from geometrical"
2112 H$(3)="     dimensions of the reactor according to the formula"
2113 H$(4)=" "
2114 H$(5)="          B²   = (2.405/R)² + (π/H)²      for cylindrical reactor"
2115 H$(6)="          B²   = (π/R)²                   for spherical reactor
2116 H$(7)=" "
2117 H$(8)="     where R and H are extrapolated radius and height of the"
2118 H$(9)="     reactor."
2120 H$(10)=STRING$(73," ") : LL=10 :GOSUB 2000
2130 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 2130
3000 CLS :BEEP:COLOR 0,7 :PRINT "ERROR":COLOR 7,0 :GOTO 960
3001 '
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
4000 ' LOAD DATA FOR EDIT
4010 OPEN "FARCON.DAT" FOR INPUT AS #1
4015 INPUT #1,NUM$
4020 INPUT #1, F,FF
4030 FOR I=1 TO 7 :INPUT #1,NU(I) : NEXT
4033 FOR I=8 TO 14:INPUT #1,NU(I) : NEXT
4035 IF FF=1 THEN 4040
4036 INPUT #1,VA,VC,VM,ENRICH,TS,TC,R,Z
4037 INPUT #1,PUO2,RIS,P  :  GOTO 4046
4040 FOR I=1  TO 11: INPUT #1,P(I) :NEXT I
4042 FOR I=12 TO 22: INPUT #1,P(I) :NEXT I
4043 FOR I=23 TO 33: INPUT #1,P(I) :NEXT I
4046 INPUT #1,NN
4050 FOR I=1 TO NN : INPUT #1,BG(I) : NEXT I
4060 CLOSE #1
4070 RETURN
```

ข-6 รายละเอียดโปรแกรม INPUT2.BAS

```
3 ON ERROR GOTO 320
5 COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7  COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
10  DIM NA$(17),H$(25),RO(20),Z1(20),VOL(20)
13  FOR I=1 TO 17 : READ NA$(I)  :NEXT I
```

```
15  DATA "HYDROGEN"," OXYGEN ","Fission Products from PLUTONIUM-239"," CARBON "
    ," PLUTONIUM-240 "," URANIUM-238  "," PLUTONIUM-242 "," URANIUM-235  ",
    " URANIUM-236  "," PLUTONIUM-239 "," PLUTONIUM-241 "," XENON-135 "
16  DATA " SAMARIUM-149 "," ZIRCALOY-2 "," Stainless Steel-304 ","BORON-10",
    "Fission Products from U235 "
18   K$="HELP":KK$=CHR$(13)
20   KEY 1,K$+KK$
23  AA$="                                  Press ESC to Exit                    "
25  CC$="   F1 for help   "  :CCC$="   RETURN if unchange"
30  CLS : LOCATE 1,30:PRINT "INPUT PREPARATION"
31  LOCATE 5,5 :PRINT "Enter [1]enter new data [2]correct old data"
32  LOCATE 7,10:PRINT C$: LOCATE 7,10:INPUT "", INX$ :   CLS
33  IF INX$="2" THEN GOSUB 4000
34  LOCATE 5,5 :PRINT "     Enter title of your job. ( < 80 character )"
38  C$=NUM$ :GOSUB 3100  : IF X$<>"" THEN NUM$=X$
90  LOCATE 5,5 :PRINT "    Enter radius of homoginized basic reactor cell.(cm)"
100 C$=STR$(RADIUS) :GOSUB 3100  : IF X$<>"" THEN RADIUS=VAL(X$)
110 LOCATE 5,5 :PRINT "    Enter buckling value. (1/cm**2) "
120 C$=STR$(BUCK) :GOSUB 3100  : IF X$<>"" THEN BUCK=VAL(X$)
130 LOCATE 5,5 :PRINT "    Enter moderator temperature. (K)  "
140 C$=STR$(T) :GOSUB 3100  : IF X$<>"" THEN T=VAL(X$)
150 OPEN "SLOCON.DAT" FOR OUTPUT AS #1
155 WRITE #1, NUM$
160 WRITE #1, RADIUS
170 WRITE #1, BUCK,T
180 FOR I=1 TO 17
190 LOCATE 5,5 :PRINT "    Enter mass density (gm/cm**3) of ";NA$(I)
200 LOCATE 6,5 :PRINT "          Enter zero(0) if absent."
210 GOSUB 3200 : C$=STR$(RO(I)) : GOSUB 3100
212 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 190
214 IF X$="" THEN 220
216 RO(I)=VAL(X$)
220 LOCATE 5,5 :PRINT "    Enter number of atoms of ";NA$(I);" per molecule"
221 GOSUB 3200 : C$=STR$(Z1(I)) : GOSUB 3100
222 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 220
224 IF X$="" THEN 240
226 Z1(I)=VAL(X$)
240 LOCATE 5,5 :PRINT "    Enter volume fraction for ";NA$(I)
250 LOCATE 6,5 :PRINT "          Enter zero(0) if absent."
251 GOSUB 3200 : C$=STR$(VOL(I)) : GOSUB 3100
252 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 240
254 IF X$="" THEN 270
256 VOL(I)=VAL(X$)
270 WRITE #1,I,RO(I),Z1(I),VOL(I)
275 NEXT I
```

```
280 LOCATE 5,5 :PRINT "    Enter energy increment. (recommended value 0.01 eV)"
290 C$=STR$(DE) :GOSUB 3100  : IF X$<>"" THEN DE=VAL(X$)
310 WRITE #1,DE
320 CLOSE #1  :   CHAIN FIL3$
1000 '
1005 H$(1)=STRING$(73," ")
1006 H$(2)="    Mass densities (Rho(i))"
1007 H$(3)="       The density of hydrogen is the density of water."
1008 H$(4)="       The density of uranium in UO2 is that of UO2."
1009 H$(5)="    Volume fraction (Vi)"
1010 H$(6)="       Volume fraction of H is equal to moderator volume fraction."
1011 H$(7)="       That of U is equal to fuel volume fraction."
1012 H$(8)="       That of Zr-2 or SS-304 is equal to clad volume fraction."
1013 H$(9)=" "
1014 H$(10)="        for U-235 ----> V(U-235) = V(U) x %enrichment/100"
1015 H$(11)="  "
1016 H$(12)="        for OXYGEN  "
1017 H$(13)="            you should give in the input for OXYGEN  "
1018 H$(14)="                mass density = 1  "
1019 H$(15)="                number of atom per molecule = 1  "
1020 H$(16)="         and calculate the volume fraction by formula   "
1021 H$(17)="        V(o) = Rho(H2O)*1*V(H2o)/18 + Rho(UO2)*2*V(UO2)/270 "
1022 H$(18)=STRING$(73," ") : LL=18 : GOSUB 2000
1195 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP : GOTO 1195
2000 CLS :  COLOR 0,7:PRINT STRING$(75," ")
2087 FOR IK=1 TO LL
2090 COLOR 0,7:PRINT" ";:COLOR 7,0:PRINT H$(IK);:COLOR 0,7:LOCATE IK+1,75:
     PRINT" ":COLOR 7,0
2092 NEXT IK
2095 COLOR 0,7:PRINT AA$ :COLOR 7,0  :RETURN
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
4000 ' LOAD DATA FOR EDIT
4010 OPEN "SLOCON.DAT" FOR INPUT AS #1
4015 INPUT #1,NUM$
4020 INPUT #1, RADIUS
4022 INPUT #1, BUCK,T
4030 FOR I=1 TO 17 : INPUT #1,I,RO(I),Z1(I),VOL(I) : NEXT
4036 INPUT #1,DE
4060 CLOSE #1
4070 RETURN
```

ข-7 รายละเอียดโปรแกรม INPUT3.BAS

```
3    ON ERROR GOTO 950
5    COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7    COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
15   K$="HELP":KK$=CHR$(13)
20   KEY 1,K$+KK$
400  AA$="                                    Press ESC to Exit                    "
450  CC$="   F1 for help   "  :CCC$="   RETURN if unchange"  : cls
511  LOCATE 5,5 :PRINT "Enter [1]enter new data [2]correct old data"
512  LOCATE 7,10:PRINT C$: LOCATE 7,10:INPUT "", INX$ :   CLS
513  IF INX$="2" THEN GOSUB 4000
514  LOCATE 5,5 :PRINT "     Enter title of your job. ( < 80 character )"
518  C$=NUM$ :GOSUB 3100  : IF X$<>"" THEN NUM$=X$
800 CLS : LOCATE 1,20:PRINT "INPUT PREPARATION"  : C$=CHR$(219)
810 BEEP : LOCATE 5,5 :PRINT "    Enter absorption cross section of moderator
    (1/cm) "
815 GOSUB 3200 : C$=STR$(SIGAM) : GOSUB 3100
816 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 810
817 IF X$="" THEN 820
818 SIGAM=VAL(X$)
820 LOCATE 5,5 :PRINT "    Enter scattering cross section of moderator (1/cm) "
825 GOSUB 3200 : C$=STR$(SIGSM) : GOSUB 3100
826 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 820
827 IF X$="" THEN 830
828 SIGSM=VAL(X$)
830 LOCATE 5,5 :PRINT "    Enter absorption cross section of fuel (1/cm) "
835 GOSUB 3200 : C$=STR$(SIGAF) : GOSUB 3100
836 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 830
837 IF X$="" THEN 840
838 SIGAF=VAL(X$)
840 LOCATE 5,5 :PRINT "    Enter scattering cross section of fuel (1/cm)"
845 GOSUB 3200 : C$=STR$(SIGSF) : GOSUB 3100
846 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 840
847 IF X$="" THEN 850
848 SIGSF=VAL(X$)
850 LOCATE 5,5 :PRINT "    Enter fission cross section of fuel (1/cm) "
845 GOSUB 3200 : C$=STR$(SIGFF) : GOSUB 3100
846 IF X$=K$ THEN GOSUB 1000 : CLS : BEEP : GOTO 850
847 IF X$="" THEN 860
848 SIGFF=VAL(X$)
860 LOCATE 5,5 :PRINT "    Enter diffusion constant of fuel (cm)"
865 C$=STR$(DIF) :GOSUB 3100  : IF X$<>"" THEN DIF=VAL(X$)
870 LOCATE 5,5 :PRINT "    Enter diffusion constant of moderator (cm) "
875 C$=STR$(DI) :GOSUB 3100  : IF X$<>"" THEN DI=VAL(X$)
880 LOCATE 5,5 :PRINT "    Enter radius of fuel rod (cm)"
```

```
885 C$=STR$(A) :GOSUB 3100  : IF X$<>"" THEN A=VAL(X$)
890 LOCATE 5,5 :PRINT "    Enter center to center distance between fuel rods
    (cm)"
895 C$=STR$(X) :GOSUB 3100  : IF X$<>"" THEN X=VAL(X$)
900 LOCATE 4,5 :PRINT "    Enter [1] for square lattice "
905 LOCATE 5,5 :PRINT "          [2] for hexagonal lattice"
910 C$=STR$(L) :GOSUB 3100  : IF X$<>"" THEN L=VAL(X$)
920 CLS : OPEN "DISFAC.DAT" FOR OUTPUT AS #1
925 WRITE #1,NUM$
930 WRITE #1,SIGAM,SIGSM,SIGAF,SIGSF,SIGFF,DIF,DI,A,X,L
940 CLOSE: CHAIN FIL3$
950 CLS : BEEP : COLOR 0,7 : PRINT "ERROR" : COLOR 7,0 : GOTO 940
1000 ' HELP FOR INPUT MODULE DISFAC
1002 H$(1)=STRING$(73," ")
1004 H$(2)="      The macroscopic cross section have to be prepared by"
1006 H$(3)="   The user as a product of the actual number density of the"
1008 H$(4)="   material and a microscopic cross section taken from standard"
1010 H$(5)="   nuclear tables. However, in standard tables the thermal cross"
1012 H$(6)="   section are usually given for neutron velocity equal to 2200"
1013 H$(7)="   M/S and the correction for Maxwellian spectrum "
1014 H$(8)="   distribution at an appropriate temperature has to introduced by"
1015 H$(9)="   the formula"
1016 H$(10)="                    σ(T°K) =σ(2200 m/s)/1.128 G(T) ∫(.0253/kT)"
1017 H$(11)="        Where k = Boltzmann constant = 8.61E-5 eV/Kelvin"
1018 H$(12)="                  T = temperature in Kelvin"
1019 H$(13)="                  G(t) = non-1/V factor"
1020 H$(14)=STRING$(73," ") : LL=14 : GOSUB 2000
1100 B$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1100
2000 CLS :  COLOR 0,7:PRINT STRING$(75," ")
2087 FOR IK=1 TO LL
2090 COLOR 0,7:PRINT" ";:COLOR 7,0:PRINT H$(IK);:COLOR 0,7:LOCATE IK+1,75:
     PRINT" ":COLOR 7,0
2092 NEXT IK
2095 COLOR 0,7:PRINT AA$ :COLOR 7,0  :RETURN
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
4000 ' LOAD DATA FOR EDIT
4010 OPEN "DISFAC.DAT" FOR INPUT AS #1
4015 INPUT #1, NUM$
4020 INPUT #1, SIGAM,SIGSM,SIGAF,SIGSF,SIGFF,DIF,DI,A,X,L
4060 CLOSE #1
4070 RETURN
```

ข-8 รายละเอียดโปรแกรม INPUT4.BAS

```
3     ON ERROR GOTO 345
5     COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7     COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
10    'INPUT PREPARATION FOR MODULE ODOG ****4****
11    K$="HELP":KK$=CHR$(13)
12    KEY 1,K$+KK$
13    AA$="                                    Press ESC to Exit
14    CC$="   F1 for help   "  :CCC$="   RETURN if unchange"
20    CLS : LOCATE 1,30:PRINT "INPUT PREPARATION"  : BEEP
21    LOCATE 5,5 :PRINT "Enter [1]enter new data [2]correct old data"
22    LOCATE 7,10:PRINT C$: LOCATE 7,10:INPUT "", INX$ :   CLS
23    IF INX$="2" THEN GOSUB 4000
24    LOCATE 5,5 :PRINT "     Enter title of your job. ( < 80 character )"
28    C$=NUM$ :GOSUB 3100  : IF X$<>"" THEN NUM$=X$
30    LOCATE 5,5 :PRINT "    Enter number of regions. ( < 6 )"
40    C$=STR$(M) : GOSUB 3100  : IF X$<>"" THEN M=VAL(X$)
50    LOCATE 5,5 :PRINT "    Enter type of geometry."
60    LOCATE 6,5 :PRINT "          [0] Plane [1] Cylinder [2] Sphere"
70    C$=STR$(NN) : GOSUB 3100  : IF X$<>"" THEN NN=VAL(X$)
80    LOCATE 5,5 :PRINT "    Enter eigenvalue convergence criterion."
90    C$=STR$(EPS) : GOSUB 3100  : IF X$<>"" THEN EPS=VAL(X$)
100   FOR I=1 TO M
110   LOCATE 5,5 :PRINT "    Enter distances (cm) from the origin to interface
      of region # ";I
120   C$=STR$(RR(I)) : GOSUB 3100  : IF X$<>"" THEN RR(I)=VAL(X$)
125   NEXT I
130   FOR I=1 TO M
140   LOCATE 5,5 :PRINT "    Enter diffusion coefficients (cm) for region # ";I
150   C$=STR$(D(I)) : GOSUB 3100  : IF X$<>"" THEN D(I)=VAL(X$)
155   NEXT I
160   FOR I=1 TO M
170   LOCATE 5,5 :PRINT "    Enter macro. absorp. cross section (1/cm) for
      region # ";I
180   C$=STR$(SIGMA(I)) : GOSUB 3100  : IF X$<>"" THEN SIGMA(I)=VAL(X$)
185   NEXT I
190   FOR I=1 TO M
200   LOCATE 5,5 :PRINT "    Enter Nu*macro. fission cross section (1/cm) for
      region # ";I
210   C$=STR$(F(I)) : GOSUB 3100  : IF X$<>"" THEN F(I)=VAL(X$)
215   NEXT I
220   LOCATE 5,5 :PRINT "    Enter axial buckling. (1/cm**2) "
230   C$=STR$(BCZ) : GOSUB 3100  : IF X$<>"" THEN BCZ=VAL(X$)
240   LOCATE 5,5 :PRINT "    Enter buckling in X-direction. (1/cm**2) "
```

```
250  C$=STR$(BPY) : GOSUB 3100  : IF X$<>"" THEN BPY=VAL(X$)
260  LOCATE 5,5 :PRINT "    Enter buckling in Y-direction. (1/cm**2) "
270  C$=STR$(BPZ) : GOSUB 3100  : IF X$<>"" THEN BPZ=VAL(X$)
280  OPEN "ODOG.DAT" FOR OUTPUT AS #1
285  WRITE #1, NUM$
290  WRITE #1, M,NN,EPS
300  WRITE #1, RR(1),RR(2),RR(3),RR(4),RR(5)
310  WRITE #1, D(1),D(2),D(3),D(4),D(5)
320  WRITE #1, SIGMA(1),SIGMA(2),SIGMA(3),SIGMA(4),SIGMA(5)
330  WRITE #1, F(1),F(2),F(3),F(4),F(5)
340  WRITE #1, BCZ,BPY,BPZ
345  CLOSE #1  :  CHAIN FIL3$
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
4000 ' LOAD DATA FOR EDIT
4010 OPEN "ODOG.DAT" FOR INPUT AS #1
4028 INPUT #1, NUM$
4029 INPUT #1, M,NN,EPS
4030 INPUT #1, RR(1),RR(2),RR(3),RR(4),RR(5)
4031 INPUT #1, D(1),D(2),D(3),D(4),D(5)
4032 INPUT #1, SIGMA(1),SIGMA(2),SIGMA(3),SIGMA(4),SIGMA(5)
4033 INPUT #1, F(1),F(2),F(3),F(4),F(5)
4034 INPUT #1, BCZ,BPY,BPZ
4060 CLOSE #1
4070 RETURN
```

ข-9 รายละเอียดโปรแกรม INPUT5.BAS

```
3  ON ERROR GOTO 710
5  COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7  COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
10 DIM H$(20)
12  K$="HELP" : KK$=CHR$(13)
14  KEY 1,K$+KK$
40  AA$="                                    Press ESC to Exit                    "
45  CC$="   F1 for help"  :  CCC$="   RETURN if unchange "  : BL$="      "
100 CLS : LOCATE 1,20:PRINT "INPUT PREPARATION"  : CLS : BEEP
102 LOCATE 5,5: PRINT "Enter [1]enter new data  [2]correct old data"
104 LOCATE 7,10 : PRINT C$ : LOCATE 7,10 : INPUT "", INX$ : CLS
106 IF INX$="2" THEN GOSUB 4000
108 BEEP : LOCATE 5,5 : PRINT "Enter title of your job ( < 80 characters )
110 C$=NUM$ : GOSUB 3100 : IF X$<>"" THEN NUM$=X$
120 LOCATE 5,5 :PRINT "    Enter left side boundary condition. "
```

```
130 LOCATE 6,5 :PRINT "          [1] zero flux  [2] zero current "
131 GOSUB 3200 : C$=STR$(BCC) : GOSUB 3100
132 IF X$=K$ THEN GOSUB 1200 : CLS : GOTO 120
133 IF X$="" THEN 150
134 BCC=VAL(X$)
150 LOCATE 5,5 :PRINT "    Enter right side boundary condition. "
160 LOCATE 6,5 :PRINT "          [1] zero flux  [2] zero current "
161 GOSUB 3200 : C$=STR$(BCR) : GOSUB 3100
162 IF X$=K$ THEN GOSUB 1200 : CLS : GOTO 150
163 IF X$="" THEN 180
164 BCR=VAL(X$)
180 LOCATE 5,5 :PRINT "    Enter type of geometry. "
190 LOCATE 6,5 :PRINT "          [0] Plane  [1] Cylinder  [2] sphere "
200 C$=STR$(P) : GOSUB 3100 : IF X$<>"" THEN P=VAL(X$)
210 LOCATE 5,5 :PRINT "    Enter number of material regions. ( < 5 ) "
220 C$=STR$(NRGNS) : GOSUB 3100 : IF X$<>"" THEN NRGNS=VAL(X$)
230 LOCATE 5,5 :PRINT "    Enter eigenvalue search option. "
240 LOCATE 6,5 :PRINT "          [0] no search  [1] poison search "
250 C$=STR$(JP) : GOSUB 3100 : IF X$<>"" THEN JP=VAL(X$)
260 LOCATE 5,5 :PRINT "    Enter eigenvalue convergence criterion.(recommended
    value= 1.E-4)"
261 GOSUB 3200 : C$=STR$(EPS) : GOSUB 3100
262 IF X$=K$ THEN GOSUB 1100 : CLS : GOTO 260
263 IF X$="" THEN 280
264 EPS=VAL(X$)
280 LOCATE 5,5 :PRINT "    Enter number of groups. ( < 4 ) "
290 C$=STR$(G) : GOSUB 3100 : IF X$<>"" THEN G=VAL(X$)
300 FOR I=1 TO NRGNS
310 LOCATE 5,5 :PRINT "    Enter width (cm) of material region # ";I
320 C$=STR$(EL(I)) : GOSUB 3100 : IF X$<>"" THEN EL(I)=VAL(X$)
322 NEXT I
330 FOR I=1 TO NRGNS : BEEP
340 FOR J=1 TO G     : LOCATE 5,25:PRINT "REGION # ";I "   GROUP # ";J  :BEEP
350 LOCATE 8,10:PRINT "    Enter diffusion coefficient (cm) "
360 C$=STR$(D(J,I)) : GOSUB 3300 : IF X$<>"" THEN D(J,I)=VAL(X$) :LOCATE 8,10:
    PRINT BL$:LOCATE 9,5:PRINT BL$
370 LOCATE 8,10:PRINT "    Enter macro. absorp. cross section (1/cm) "
380 C$=STR$(SA(J,I)) : GOSUB 3300 : IF X$<>"" THEN SA(J,I)=VAL(X$):LOCATE 8,10:
    PRINT BL$:LOCATE 9,5:PRINT BL$
390 LOCATE 8,10:PRINT "    Enter macro. removal cross section (1/cm) "
400 C$=STR$(SR(J,I)) :GOSUB 3300 : IF X$<>"" THEN SR(J,I)=VAL(X$) :LOCATE 8,10
    :PRINT BL$:LOCATE 9,5:PRINT BL$
410 LOCATE 8,10:PRINT "    Enter nu * macro. fission cross section (1/cm) "
420 C$=STR$(SF(J,I)) : GOSUB 3300 : IF X$<>"" THEN SF(J,I)=VAL(X$) :LOCATE 8,
    10:PRINT BL$:LOCATE 9,5:PRINT BL$
```

```
430 LOCATE 8,10:PRINT "    Enter macro. poison absorption cross section (1/cm)"
440 C$=STR$(SP(J,I)) : GOSUB 3300 : IF X$<>"" THEN SP(J,I)=VAL(X$) :LOCATE 8,
    10:PRINT BL$:LOCATE 9,5:PRINT BL$
450 LOCATE 8,10:PRINT "    Enter nu"
460 C$=STR$(SNU(J,I)) : GOSUB 3300 : IF X$<>"" THEN SNU(J,I)=VAL(X$) :LOCATE
    8,10:PRINT BL$:LOCATE 9,5:PRINT BL$
470 LOCATE 8,10:PRINT "    Enter buckling (1/cm**2)"
471 GOSUB 3200 : C$=STR$(BUCK(J,I)) : GOSUB 3300
472 IF X$=K$ THEN GOSUB 1300 : CLS : GOTO 470
473 IF X$="" THEN 490
474 BUCK(J,I)=VAL(X$)
480 'LOCATE 23,10 :PRINT BL$ :LOCATE 9,5:PRINT BL$ : GOTO 490
484 'CLS :BEEP : LOCATE 5,25:PRINT "REGION # ";I;"   GROUP # ";J : GOTO 470
490 NEXT J
495 NEXT I
500 LOCATE 5,5 :PRINT "    Enter power level (watts)"
510 C$=STR$(POWER) : GOSUB 3100 : IF X$<>"" THEN POWER=VAL(X$)
520 LOCATE 5,5 :PRINT "    Enter height (cm) for CYLINDER, "
530 LOCATE 6,5 :PRINT "          height * depth for SLAB OR enter 1 for SPHERE"
540 C$=STR$(HT) : GOSUB 3100 : IF X$<>"" THEN HT=VAL(X$)
550 IF JS=0 THEN 600
560 LOCATE 5,5 :PRINT "    Enter designed Keff value for poison search "
570 C$=STR$(DESEIG) : GOSUB 3100 : IF X$<>"" THEN DESEIG=VAL(X$)
580 LOCATE 5,5 :PRINT "    Enter convergence criterion for poison search.
    (recommended value=1.E-3)"
590 C$=STR$(EPS2) : GOSUB 3100 : IF X$<>"" THEN EPS2=VAL(X$)
600 OPEN "ODMUG.DAT" FOR OUTPUT AS #1
605 WRITE #1, NUM$
610 WRITE #1,BCC,BCR,P,NRGNS,JP,EPS,G
620 WRITE #1,EL(1),EL(2),EL(3),EL(4),EL(5)
630 FOR I=1 TO NRGNS
640 FOR J=1 TO G
650 WRITE #1,D(J,I),SA(J,I),SR(J,I),SF(J,I),SP(J,I),SNU(J,I),BUCK(J,I)
660 NEXT J,I
670 WRITE #1,POWER,HT
680 IF JP=0 THEN 700
690 WRITE #1,DESEIG,EPS2
700 CLOSE #1  :  CHAIN FIL3$
710 CLS:BEEP:COLOR 0,7:PRINT"ERROR":COLOR 7,0: GOTO 700
1000 CLS :  COLOR 0,7:PRINT STRING$(75," ")
1087  FOR IK=1 TO LL
1090 COLOR 0,7:PRINT" ";:COLOR 7,0:PRINT H$(IK);:COLOR 0,7:LOCATE IK+1,75:
    PRINT" ":COLOR 7,0
1092 NEXT IK
1095 COLOR 0,7:PRINT AA$ :COLOR 7,0  :RETURN
```

```
1100  H$(1)=STRING$(73," ")
1105  H$(2)="   If this value < 0 the full information on convergence history"
1110  H$(3)=" is printed. If this value > 0 only the information on the last"
1115  H$(4)=" iteration is printed. In convergence checking the absolute"
1120  H$(5)=" value of this value is used."
1145  H$(6)=STRING$(73," ") : LL=6 :GOSUB 1000
1150 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1150
1200  H$(1)=STRING$(73," ")
1205  H$(2)="          The type of boundary conditions chosen in input must be"
1210  H$(3)="     consistent with the problem geometry, i.e. a zero current"
1215  H$(4)="     boundary condition is used in the sphere and cylinder"
1220  H$(5)="     center."
1245  H$(6)=STRING$(73," ") : LL=6 :GOSUB 1000
1250 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1250
1300  H$(1)=STRING$(73," ")
1305  H$(2)="          The buckling value given by the user corresponds to the"
1310  H$(3)="     transverse buckling i.e. the axial buckling for cylindrical"
1315  H$(4)="     geometry"
1320  H$(5)=" "
1325  H$(6)="                    B²z   =  (π/Hz)²"
1330  H$(7)=" "
1335  H$(8)="     and in the case of a plane geometry"
1340  H$(9)=" "
1345  H$(10)="          B²x + B²y   = (π/Hx)² + (π/Hy)²"
1350  H$(11)=" "
1355  H$(12)="    where Hx  Hy  Hz are the effective dimensions of the reactor"
1360  H$(13)=STRING$(73," ") : LL=13:GOSUB 1000
1365 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP:GOTO 1365
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
3300 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3310 LOCATE 9,10:PRINT C$: LOCATE 9,11:INPUT "",X$  : CLS : RETURN
4000 ' ****** LOAD DATA FOR EDIT *****
4005 OPEN "ODMUG.DAT" FOR INPUT AS #1
4008 INPUT #1, NUM$
4010 INPUT #1, BCC,BCR,P,NRGNS,JP,EPS,G
4020 INPUT #1, EL(1),EL(2),EL(3),EL(4),EL(5)
4030 FOR I=1 TO NRGNS
4040 FOR J=1 TO G
4050 INPUT #1, D(J,I),SA(J,I),SR(J,I),SF(J,I),SP(J,I),SNU(J,I),BUCK(J,I)
4060 NEXT J,I
4070 INPUT #1, POWER,HT
4080 IF JP=0 THEN 4100
4090 INPUT #1, DESEIG,EPS2
```

```
4100 CLOSE #1
4170 RETURN
```

ข-10 รายละเอียดโปรแกรม INPUT6.BAS

```
3    ON ERROR GOTO 1980
5    COMMON FIL1$,FIL2$,FIL3$,MAI$,TIT$,IP$,SHEL$,COP$
7    COMMON P$,P1$,S1$,S2$,S3$,S4$,S5$,S6$,S7$,DX1$,DX2$
8    DIM H$(20)
10   K$="HELP":KK$=CHR$(13)
20   KEY 1,K$+KK$
30   AA$="                                    Press ESC to Exit                    "
40   CC$="   F1 for help   "  :CCC$="   RETURN if unchange" : CLS : BEEP
51   LOCATE 5,5 :PRINT "Enter [1]enter new data [2]correct old data"
52   LOCATE 7,10:PRINT C$: LOCATE 7,10:INPUT "", INX$ :   CLS
53   IF INX$="2" THEN GOSUB 4000
54   LOCATE 5,5 :PRINT "     Enter title of your job. ( < 80 character )"
58   C$=NUM$ :GOSUB 3100  : IF X$<>"" THEN NUM$=X$
1500 BEEP : CLS : LOCATE 1,30:PRINT "INPUT PREPARATION"
1510 LOCATE 5,5 :PRINT "    Enter initial mass density of U-235 (gm/cm**3) "
1520 GOSUB 3200 : C$=STR$(M5(1)) : GOSUB 3100
1522 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1510
1524 IF X$="" THEN 1530
1526 M5(1)=VAL(X$)
1530 LOCATE 5,5 :PRINT "    Enter initial mass density of U-236 (gm/cm**3) "
1531 GOSUB 3200 : C$=STR$(M6(1)) : GOSUB 3100
1532 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1530
1534 IF X$="" THEN 1550
1536 M6(1)=VAL(X$)
1550 LOCATE 5,5 :PRINT "    Enter initial mass density of U-238 (gm/cm**3) "
1551 GOSUB 3200 : C$=STR$(M8(1)) : GOSUB 3100
1552 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1550
1554 IF X$="" THEN 1570
1556 M8(1)=VAL(X$)
1570 LOCATE 5,5 :PRINT "    Enter initial mass density of Pu-239 (gm/cm**3) "
1571 GOSUB 3200 : C$=STR$(M9(1)) : GOSUB 3100
1572 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1570
1574 IF X$="" THEN 1590
1576 M9(1)=VAL(X$)
1590 LOCATE 5,5 :PRINT "    Enter initial mass density of Pu-240 (gm/cm**3) "
1591 GOSUB 3200 : C$=STR$(M0(1)) : GOSUB 3100
1592 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1590
1594 IF X$="" THEN 1610
1596 M0(1)=VAL(X$)
```

```
1610 LOCATE 5,5 :PRINT "    Enter initial mass density of Pu-241 (gm/cm**3) "
1611 GOSUB 3200 : C$=STR$(M1(1)) : GOSUB 3100
1612 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1610
1614 IF X$="" THEN 1630
1616 M1(1)=VAL(X$)
1630 LOCATE 5,5 :PRINT "    Enter initial mass density of Pu-242 (gm/cm**3) "
1631 GOSUB 3200 : C$=STR$(M2(1)) : GOSUB 3100
1632 IF X$=K$ THEN GOSUB 2200 : CLS : BEEP : GOTO 1630
1634 IF X$="" THEN 1645
1636 M2(1)=VAL(X$)
1645 FOR I=1 TO 2
1650 LOCATE 5,5 :PRINT " Enter macro. removal cross section (1/cm) for
     group # ";I
1660 C$=STR$(SIGR(I)) : GOSUB 3100  : IF X$<>"" THEN SIGR(I)=VAL(X$)
1665 NEXT I
1668 FOR I=1 TO 3
1670 LOCATE 5,5 :PRINT " Enter diffusion coefficients for group # ";I
1680 C$=STR$(DF(I)) : GOSUB 3100  : IF X$<>"" THEN DF(I)=VAL(X$)
1685 NEXT I
1690 LOCATE 5,5 :PRINT " Enter buckling (1/cm**2)"
1691 GOSUB 3200 : C$=STR$(BG) : GOSUB 3100
1692 IF X$=K$ THEN GOSUB 2000 : CLS : BEEP : GOTO 1690
1694 IF X$="" THEN 1710
1696 BG=VAL(X$)
1710 LOCATE 5,5 :PRINT " Enter number of burnup steps "
1720 C$=STR$(JJ) : GOSUB 3100  : IF X$<>"" THEN JJ=VAL(X$)
1730 LOCATE 5,5 :PRINT " Enter power density (watt/cm**3) "
1740 C$=STR$(P) : GOSUB 3100  : IF X$<>"" THEN P=VAL(X$)
1750 LOCATE 5,5 :PRINT " Enter burnup step length (hours) "
1760 C$=STR$(T0) : GOSUB 3100  : IF X$<>"" THEN T0=VAL(X$)
1765 FOR I=1 TO 3
1770 LOCATE 5,5 :PRINT " Enter macro. absorption cross section (1/cm)
     homogenized "
1780 LOCATE 6,5 :PRINT "       over clad and moderator for group # ";I
1791 GOSUB 3200 : C$=STR$(SIGA3(I)) : GOSUB 3100
1792 IF X$=K$ THEN GOSUB 2300 : CLS : BEEP : GOTO 1770
1794 IF X$="" THEN 1800
1796 SIGA3(I)=VAL(X$)
1797 NEXT I
1800 LOCATE 5,5 :PRINT " Enter macro. cell absorp.cross section for group 1
     (fast) "
1810 C$=STR$(SIG1A) : GOSUB 3100  : IF X$<>"" THEN SIG1A=VAL(X$)
1820 LOCATE 5,5 :PRINT " Enter macro. cell absorp.cross section for group 2
     (epithermal) "
1830 C$=STR$(SIG2A) : GOSUB 3100  : IF X$<>"" THEN SIG2A=VAL(X$)
```

```
1840 LOCATE 5,5 :PRINT " Enter macro. cell absorp.cross section for group 3
     (thermal) "
1850 C$=STR$(SIGMAA) : GOSUB 3100  : IF X$<>"" THEN SIGMAA=VAL(X$)
1860 LOCATE 5,5 :PRINT "Enter Nu * macro. cell fission cross section for group1
     (fast) "
1870 C$=STR$(NSIGF1) : GOSUB 3100  : IF X$<>"" THEN NSIGF1=VAL(X$)
1880 LOCATE 5,5 :PRINT "Enter Nu * macro. cell fission cross section for group2
     (epithermal)"
1890 C$=STR$(NSIGF2) : GOSUB 3100  : IF X$<>"" THEN NSIGF2=VAL(X$)
1900 LOCATE 5,5 :PRINT "Enter Nu * macro. cell fission cross section for group3
     (thermal)"
1910 C$=STR$(SFISS) : GOSUB 3100  : IF X$<>"" THEN SFISS=VAL(X$)
1920 OPEN "FBURN.DAT" FOR OUTPUT AS #1
1925 WRITE #1, NUM$
1930 WRITE #1, M5(1),M6(1),M8(1),M9(1),M0(1),M1(1),M2(1)
1940 WRITE #1, SIGR(1),SIGR(2),DF(1),DF(2),DF(3),BG,JJ
1950 WRITE #1, P,T0,SIGA3(1),SIGA3(2),SIGA3(3)
1960 WRITE #1, SIG1A,SIG2A,SIGMAA,NSIGF1,NSIGF2,SFISS
1970 CLOSE #1  :  CHAIN FIL3$
1980 CLS:BEEP:COLOR 0,7:PRINT "ERROR":COLOR 7,0:GOTO 1970
2000 ' HELP
2005 H$(1)=STRING$(73," ")
2010 H$(2)="          The buckling value may be estimated from geometrical"
2020 H$(3)="     dimensions of the reactor according to the formula"
2030 H$(4)=" "
2040 H$(5)="          B^2   = (2.405/R)^2 + (π/H)^2      for cylindrical reactor"
2050 H$(6)="          B^2   = (π/R)^2                    for spherical reactor"
2055 H$(7)="          B^2   = (π/Hx)^2+(π/Hy)^2+(π/Hz)^2 for slab reactor"
2056 H$(8)=" "
2060 H$(9)="     where R and H are extrapolated radius and height of the"
2070 H$(10)="     reactor."
2080 H$(11)=STRING$(73," ") : LL=11 :GOSUB 2100
2090 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP :GOTO 2090
2095 '
2100 CLS :  COLOR 0,7:PRINT STRING$(75," ")
2187 FOR IK=1 TO LL
2190 COLOR 0,7:PRINT" ";:COLOR 7,0:PRINT H$(IK);:COLOR 0,7:LOCATE IK+1,75:
     PRINT" ":COLOR 7,0
2192 NEXT IK
2195 COLOR 0,7:PRINT AA$ :COLOR 7,0  :RETURN
2200 'HELP FOR CALCULATION OF MASS DENSITY
2202 H$(1)=STRING$(73," ")
2205 H$(2)="          Mass density is calculated by formula "
2210 H$(3)=" "
2215 H$(4)="          M(i) = N(i)*A(i)/.602 "
```

```
2220 H$(5)="  where  M(i) mass density (gm/cc) of isotope i "
2225 H$(6)="         N(i) number density (atom/barn-cm) of isotope i "
2230 H$(7)="         A(i) atomic mass (amu) of isotope i "
2240 H$(8)=STRING$(73," ") : LL=8 :GOSUB 2100
2250 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP :GOTO 2250
2300 'HELP FOR CLAD-COOL
2302 H$(1)=STRING$(73," ")
2305 H$(2)="         To produce the macro. absorp. cross section homogenized"
2310 H$(3)="      over clad and moderator for fast and resonance energy groups"
2315 H$(4)="      a special run of FARCON is needed for a basic cell composed"
2320 H$(5)="      of clad and moderator materials. Absorption cross section "
2325 H$(6)="      for the thermal group can be produced by SLOCON "
2330 H$(7)=STRING$(73," ") : LL=7 :GOSUB 2100
2340 BB$=INPUT$(1) : IF BB$=CHR$(27) THEN RETURN ELSE BEEP :GOTO 2340
3100 IF INX$="2" THEN LOCATE 23,10:PRINT CCC$:COLOR 7,0
3110 LOCATE 7,10:PRINT C$: LOCATE 7,11:INPUT "",X$  : CLS : RETURN
3200 LOCATE 23,10:PRINT CC$ :COLOR 7,0 : RETURN
4000 ' ****** LOAD DATA FOR EDIT *****
4010 OPEN "FBURN.DAT" FOR INPUT AS #1
4015 INPUT #1, NUM$
4030 INPUT #1, M5(1),M6(1),M8(1),M9(1),M0(1),M1(1),M2(1)
4040 INPUT #1, SIGR(1),SIGR(2),DF(1),DF(2),DF(3),BG,JJ
4050 INPUT #1, P,T0,SIGA3(1),SIGA3(2),SIGA3(3)
4055 INPUT #1, SIG1A,SIG2A,SIGMAA,NSIGF1,NSIGF2,SFISS
4060 CLOSE #1
4070 RETURN
```

ข-11 รายละเอียดโปรแกรม NEWVER.BAS

```
5   COMMON SUM,NREG,REF
10  COLOR 7,0 : PI=3.14159 : AVO=.602
80  CLS : I=2 : LOCATE I,5 : BEEP:BEEP
100 CLS : I=2 : LOCATE I,5
110 PRINT"[0] start [1] restart"
112 LOCATE 8,5:PRINT"If 0 is choose, reactor data at the beginning of"
113 LOCATE 9,5:PRINT"core life are given by the user."
114 LOCATE 11,5:PRINT"If 1 is choose, program execution by using old"
115 LOCATE 12,5:PRINT"reactor data and the output of module FBURN"
117 A=IST : GOSUB 3600 : IST=A   'input subroutine
120 IF IST=1 THEN GOSUB 3000 : GOTO 500  'read file data.all, go to transfer
130 IF IST<>0 THEN 100
150 CLS : I=I+2 : LOCATE I,5
160 PRINT"[0] enter new data  [1] edit old data": A=ST : GOSUB 3600 : ST=A
170 IF ST=1 THEN GOSUB 3000 : GOSUB 3130 : GOTO 450 'edit data,go to save
```

```
    data.all, compute and transfer
180 IF ST<>0 THEN 150
185 CLS : LOCATE 5,5 : INPUT "ENTER title of your job : ",TITLE$
190 ' enter new data
300  CLS : GOSUB 1500  : ' CALL CORE
320  CLS : GOSUB 1700  : ' CALL CELL
340  CLS : GOSUB 1900  : ' CALL FUEL
360  CLS : GOSUB 2100  : ' CALL CLAD
380  CLS : GOSUB 2200  : ' CALL MOD
400  CLS : GOSUB 2300  : ' CALL BURN
420  CLS : GOSUB 2400  : ' CALL CRIT
440  CLS : GOSUB 2500  : ' CALL OTHERS
450 OPEN "DATA.ALL" FOR OUTPUT AS #1
455 PRINT #1,TITLE$
460 WRITE #1,XL,NREG,REG(1),REG(2),REG(3),REG(4),REG(5)
462 WRITE #1,HT,POWER,REF,SUM
464 WRITE #1,EPS,SEARCH
466 WRITE #1,DESEIG,EPSP
468 FOR II=1 TO NREG
470 WRITE #1,XC(II),RADIUS(II),THICK(II),PITCH(II)
472 WRITE #1,RHOU(II),ENRICH(II),TS(II),TC(II)
474 WRITE #1,TYPE(II),RHOC(II)
476 WRITE #1,RHOW(II),TM(II)
478 WRITE #1,STP(II),P(II),T0(II)
480 WRITE #1,NC(II),NB(II),NBE(II)
483 NEXT II
484 IF REF<>0 THEN WRITE #1,NNB
485 CLOSE #1
500 'calculation and transfer data to each module.
505 FOR II=1 TO NREG
507 IF XC(II)=1 THEN RAD(II)=SQR(SQR(3)/4/PI)*PITCH(II) ELSE RAD(II)=
    PITCH(II)/SQR(PI)
510 VT(II)=PI*RAD(II)^2
512 VA(II)=PI*(RADIUS(II)-THICK(II))^2/VT(II)
514 VC(II)=PI*(RADIUS(II)^2-(RADIUS(II)-THICK(II))^2)/VT(II)
516 VM(II)=1-PI*RADIUS(II)^2/VT(II)
518 HY(II)=RHOW(II)*AVO*2*VM(II)/18 :OX(II)=HY(II)/2+AVO*RHOU(II)*2*VA(II)/270
520 U8(II)=RHOU(II)*AVO*VA(II)*(1-ENRICH(II)/100)/270
522 U5(II)=RHOU(II)*AVO*VA(II)*ENRICH(II)/100/270
523 ZR(II)=0 : SS(II)=0
524 IF TYPE(II)=0 THEN ZR(II)=RHOC(II)*AVO*VC(II)/90 ELSE SS(II)=RHOC(II)*AVO
    *VC(II)/60
526 IF ZR(II)=ZR(1) AND SS(II)=SS(1) AND VM(II)=VM(1) THEN COOL(II)=0 ELSE
    COOL(II)=1
528 NEXT II : COOL(1)=1  'COOL=1 -compute clad-coolant , COOL=0  not compute
```

```
529 SUM=COOL(1)+COOL(2)+COOL(3)+COOL(4)+COOL(5)  'sent value of SUM to compute
    the time
530 IF XL=1 THEN BG=(2.405/(REG(NREG)+REF))^2+(PI/HT)^2 : TBUCK=(PI/HT)^2 :
    GOTO 550
531 ' transverse buckling of sphere
532 IF XL=2 THEN BG=(PI/(REG(NREG)+REF))^2      : TBUCK=0      : GOTO 550
533 'transverse buckling of plane
534 IF XL=0 THEN BG=(PI/HT)^2+(PI/REG(NREG))^2+(PI/DP)^2: TBUCK=(PI/HT)^2
    +(PI/DP)^2 : GOTO 550
550 FOR II=1 TO NREG    'homogenized clad-coolant for each zone
552 IF COOL(II)=1 THEN VTT(II)=VC(II)+VM(II) : VCC(II)=VC(II)/VTT(II) :
    VMM(II)=VM(II)/VTT(II)
554 ZRR(II)=ZR(II)/VC(II)*VCC(II) : SSS(II)=SS(II)/VC(II)*VCC(II) : HYY(II)
    =HY(II)/VM(II)*VMM(II) : OXX(II)=HYY(II)/2 : NBB(II)=NB(II)/VM(II)*VMM(II)
572 NEXT II
573 'prepare data for OGMUG
576 IF XL=0 THEN HT=HT*DP ELSE IF XL=2 THEN HT=1 ELSE HT=HT
578 FOR II=1 TO NREG :DL(II)=REG(II)-DL(II-1) : NEXT II
580 IF XL=1 OR XL=2 THEN BCC=2:BCR=1 ELSE BCC=2:BCR=1
600 ' write data file for ============> FARCON
602 HHY=HY(1)/VM(1) : OOX=HHY/2 : NNB=NNB   'H-O-Bo in reflector
605 OPEN "FARCON.DAT" FOR OUTPUT AS #1
610 F=0 : FF=0 : RIS=24 : P33=1  'set no print library and REP cal. by PGM
615 PRINT #1, TITLE$
617 WRITE #1, IST
620 WRITE #1, F,FF,NREG
623 FOR II=1 TO NREG
625 WRITE #1, ZR(II),HY(II),OX(II),NBE(II),NB(II),NC(II),SS(II)
626 WRITE #1, U5(II),U6(II),U8(II),PU9(II),PU0(II),PU1(II),PU2(II)
627 WRITE #1, VA(II),VC(II),VM(II),ENRICH(II)/100,TS(II),TC(II),RADIUS(II),
    XC(II)
628 WRITE #1, RHOU(II),RIS,P33
629 WRITE #1, BG
630 WRITE #1, COOL(II),ZRR(II),SSS(II),HYY(II),OXX(II),NBB(II)
631 IF COOL(II)=0 THEN 643
639 WRITE #1, 0,VCC(II),VMM(II),ENRICH(II)/100,TS(II),TC(II),RADIUS(II),XC(II)
640 WRITE #1, 0,RIS,P33
641 WRITE #1, BG
643 NEXT II
644 WRITE #1, REF,HHY,OOX,NNB          'reflector compositions
646 CLOSE #1
648 ' write data file for ============> SLOCON
650 OPEN "SLOCON.DAT" FOR OUTPUT AS #1
651 DE=0.01
652 PRINT #1, TITLE$
```

```
653 WRITE #1, IST,NREG
654 FOR II=1 TO NREG
656 WRITE #1, RAD(II),BG,TM(II)
658 WRITE #1, HY(II),OX(II),FPP(II),NC(II),PU0(II),U8(II)
660 WRITE #1, PU2(II),U5(II),U6(II),PU9(II),PU1(II),X5(II)
662 WRITE #1, SM9(II),ZR(II),SS(II),NB(II),FPU(II)
664 WRITE #1, DE
666 WRITE #1, COOL(II),ZRR(II),SSS(II),HYY(II),OXX(II),NBB(II)
668 NEXT II
670 WRITE #1, REF,HHY,OOX,NNB                ' * reflector compositions
678 CLOSE #1
680 ' write data file for ==============> FUELBURN
682 OPEN "FBURN.DAT" FOR OUTPUT AS #1
684 PRINT #1, TITLE$
686 WRITE #1, NREG
688 FOR II=1 TO NREG
692 WRITE #1, BG,STP(II),P(II),T0(II)
694 NEXT II
696 CLOSE #1
700 ' write data file for ==============> ODMUG
701 G=3  ' 3 energy groups
702 OPEN "ODMUG.DAT" FOR OUTPUT AS #1
704 PRINT #1, TITLE$
708 WRITE #1, BCC,BCR,XL,NREG,SEARCH,EPS,G
710 WRITE #1, DL(1),DL(2),DL(3),DL(4)
711 WRITE #1, REF,TBUCK
712 WRITE #1, POWER*1.E6,HT
714 IF SEARCH<>1 THEN 718
716 WRITE #1, DESEIG,EPSP
718 CLOSE #1
750 CHAIN "PLINK.BAS"
1490 END
1500 ' SUBROUTINE CORE DATA
1510 I=2          :BEEP : GOSUB 3500
1520 LOCATE I,25 : PRINT "CORE DATA "
1530 I=I+2 : LOCATE I,5
1540 PRINT"core geometry [0]plane [1]cylinder [2]sphere": A=XL : GOSUB 3600 :
     XL=A
1550 I=I+2 : LOCATE I,5
1560 PRINT"number of fuel zones ":  A=NREG : GOSUB 3600 : NREG=A
1570 FOR II=1 TO NREG
1580 I=I+2 : LOCATE I,5
1590 PRINT"external radius (cm) of region # ";II :  A=REG(II) : GOSUB 3600 :
     REG(II)=A
1600 NEXT II
```

```
1602 I=I+2 : LOCATE I,5
1604 PRINT"water reflector thickness (cm) [ enter 0 if absent]" : A=REF :
     GOSUB 3600 : REF=A
1610 I=I+2 : LOCATE I,5
1620 PRINT"height of core (cm) ( 1 if sphere)   " :  A=HT : GOSUB 3600 : HT=A
1622 IF XL=0 THEN I=I+2:LOCATE I,5:PRINT"depth of core (cm)                    "
     :  A=DP : GOSUB 3600 : DP=A
1630 I=I+2 : LOCATE I,5
1640 PRINT"thermal power (Mwatt)              " : A=POWER : GOSUB 3600 : POWER=A
1650 I=I+2 : LOCATE I,5
1660 GOSUB 3700
1670 IF Y$="y" OR Y$="Y" THEN 1500
1680 RETURN
1700 ' SUBROUTINE CELL DATA
1710 FOR II=1 TO NREG  : I=2 :BEEP : GOSUB 3500
1720 LOCATE I,25 : PRINT "CELL DATA ";:COLOR 16,7:PRINT " ZONE # ";II :
1730 I=I+2 : LOCATE I,5
1740 PRINT"cell geometry  [0]square [1]hexagonal ":IF ST=0 THEN A=XC(1)
     ELSE A=XC(II)
1745 GOSUB 3600 :  XC(II)=A
1750 I=I+2 : LOCATE I,5
1760 PRINT"rod radius (cm)   ": IF ST=0 THEN A=RADIUS(1) ELSE A=RADIUS(II)
1765 GOSUB 3600 : RADIUS(II)=A
1780 I=I+2 : LOCATE I,5
1790 PRINT"cladding thickness (cm) " : IF ST=0 THEN A=THICK(1) ELSE
     A=THICK(II)
1795 GOSUB 3600 :  THICK(II)=A
1810 I=I+2 : LOCATE I,5
1820 PRINT"lattice pitch (cm)  " :IF ST=0 THEN A=PITCH(1) ELSE A=PITCH(II)
1825 GOSUB 3600 : PITCH(II)=A
1850 I=I+2 : LOCATE I,5
1860 GOSUB 3700
1870 IF Y$="y" OR Y$="Y" THEN 1700
1875 NEXT II
1880 RETURN
1900 ' SUBROUTINE FUEL DATA
1910 FOR II=1 TO NREG : I=2  :BEEP : GOSUB 3500
1920 LOCATE I,25 : PRINT "FUEL DATA ";:COLOR 16,7:PRINT " ZONE # ";II
1930 I=I+2 : LOCATE I,5
1940 PRINT"fuel (UO2) density (gm/cc) ":IF ST=0 THEN A=RHOU(1) ELSE A=RHOU(II)
1945 GOSUB 3600 : RHOU(II)=A
1950 I=I+2 : LOCATE I,5
1960 PRINT"fuel enrichment (percent)":IF ST=0 THEN A=ENRICH(1) ELSE
     A=ENRICH(II)
1965 GOSUB 3600 :  ENRICH(II)=A
```

```
1980 I=I+2 : LOCATE I,5
1990 PRINT"fuel surface temperature (K) " :IF ST=0 THEN A=TS(1) ELSE A=TS(II)
1995 GOSUB 3600 : TS(II)=A
2010 I=I+2 : LOCATE I,5
2020 PRINT"fuel center temperature (K)  " :IF ST=0 THEN A=TC(1) ELSE A=TC(II)
2025 GOSUB 3600 : TC(II)=A
2050 I=I+2 : LOCATE I,5
2060 GOSUB 3700
2070 IF Y$="y" OR Y$="Y" THEN 1900
2075 NEXT II
2080 RETURN
2100 ' SUBROUTINE CLADDING DATA
2110 FOR II=1 TO NREG : I=2 :BEEP : GOSUB 3500
2120 LOCATE I,25 : PRINT "CLAD DATA ";:COLOR 16,7:PRINT " ZONE # ";II
2130 I=I+2 : LOCATE I,5
2140 PRINT"type of clad  [0] Zircaloy-2 [1] SS-304 ": IF ST=0 THEN A=TYPE(1)
     ELSE A=TYPE(II)
2145 GOSUB 3600 : TYPE(II)=A
2150 I=I+2 : LOCATE I,5
2160 PRINT"clad density (gm/cc)    ":IF ST=0 THEN A=RHOC(1) ELSE A=RHOC(II)
2165 GOSUB 3600 : RHOC(II)=A
2168 I=I+2 : LOCATE I,5
2170 GOSUB 3700
2180 IF Y$="y" OR Y$="Y" THEN 2100
2185 NEXT II
2190 RETURN
2200 ' SUBROUTINE MODERATOR DATA
2210 FOR II=1 TO NREG : I=2 :BEEP : GOSUB 3500
2220 LOCATE I,15 : PRINT "MODERATOR DATA [LIGHT WATER] ";:COLOR 16,7:PRINT
     " ZONE # ";II : COLOR 7
2230 I=I+2 : LOCATE I,5
2240 PRINT"density (gm/cc) ":IF ST=0 THEN A=RHOW(1) ELSE A=RHOW(II)
2245 GOSUB 3600 : RHOW(II)=A
2250 I=I+2 : LOCATE I,5
2260 PRINT"moderator temperature (K) ":IF ST=0 THEN A=TM(1) ELSE A=TM(II)
2265 GOSUB 3600 : TM(II)=A
2270 I=I+2 : LOCATE I,5
2280 GOSUB 3700
2290 IF Y$="y" OR Y$="Y" THEN 2200
2293 NEXT II
2295 RETURN
2300 ' SUBROUTINE BURNUP DATA
2310 FOR II=1 TO NREG : I=2 :BEEP : GOSUB 3500
2320 LOCATE I,25 : PRINT "BURNUP DATA ";:COLOR 16,7:PRINT " ZONE # ";II
2330 I=I+2 : LOCATE I,5
```

```
2340 PRINT"number of burnup steps ":IF ST=0 THEN A=STP(1) ELSE A=STP(II)
2345 GOSUB 3600 : STP(II)=A
2350 I=I+2 : LOCATE I,5
2360 PRINT"power density (watt/cc) ":IF ST=0 THEN A=P(1) ELSE A=P(II)
2363 GOSUB 3600 : P(II)=A
2364 I=I+2 : LOCATE I,5
2368 PRINT"burnup step length (hours) ": IF ST=0 THEN A=T0(1) ELSE A=T0(II)
2369 GOSUB 3600 : T0(II)=A
2370 I=I+2 : LOCATE I,5
2380 GOSUB 3700
2390 IF Y$="y" OR Y$="Y" THEN 2300
2393 NEXT II
2395 RETURN
2400 ' SUBROUTINE CRITICALITY DATA
2410 I=2  :BEEP : GOSUB 3500
2420 LOCATE I,25 : PRINT "CRITICALITY DATA [FOR WHOLE CORE]"
2430 I=I+2 : LOCATE I,5
2440 PRINT"convergence criterion (recommended=0.0001) ": A=EPS : GOSUB 3600 :
     EPS=A
2450 I=I+2 : LOCATE I,5
2460 PRINT"[0] no poison search [1] poison search ": A=SEARCH : GOSUB 3600 :
     SEARCH=A
2462 IF SEARCH=0 THEN 2478
2464 I=I+2 : LOCATE I,5
2468 PRINT"desired Keff value for poison search ": A=DESEIG : GOSUB 3600 :
     DESEIG=A
2470 I=I+2 : LOCATE I,5
2474 PRINT"convergence criterion (recommended=0.001) ":  A=EPSP : GOSUB 3600 :
     EPSP=A
2478 I=I+2 : LOCATE I,5
2480 GOSUB 3700
2490 IF Y$="y" OR Y$="Y" THEN 2400
2495 RETURN
2500 ' SUBROUTINE OTHERS DATA  :  ZO$="  ZONE #  "
2510 FOR II=1 TO NREG : I=2 :BEEP : GOSUB 3500
2520 LOCATE I,25 : PRINT "OTHERS DATA ";:COLOR 16,7:PRINT ZO$;II : COLOR 7
2530 I=I+2 : LOCATE I,5
2540 PRINT"number density of CARBON in the cell (atom/barn-cm) ":IF ST=0 THEN
     A=NC(1) ELSE A=NC(II)
2545 GOSUB 3600 : NC(II)=A
2550 I=I+2 : LOCATE I,5
2560 PRINT"number density of BORON in the cell (atom/barn-cm) ":IF ST=0 THEN
     A=NB(1) ELSE A=NB(II)
2563 GOSUB 3600 : NB(II)=A
2564 I=I+2 : LOCATE I,5
```

```
2568 PRINT"number density of BERILLIUM in the cell (atom/barn-cm) ":IF ST=0
     THEN A=NBE(1) ELSE A=NBE(II)
2569 GOSUB 3600 : BE(II)=A
2570 I=I+2 : LOCATE I,5
2571 IF II=NREG THEN BEEP : PRINT "number density of BORON in the reflector
     (atom/barn-cm) ":IF ST=0 THEN A=NB(1) ELSE A=NNB
2572 GOSUB 3600 : NNB=A
2573 I=I+2 : LOCATE I,5
2580 GOSUB 3700
2590 IF Y$="y" OR Y$="Y" THEN 2500
2593 NEXT II
2595 RETURN
3000 ' start sub read old data
3010 OPEN "DATA.ALL" FOR INPUT AS #1
3015 INPUT #1,TITLE$
3020 INPUT #1,XL,NREG,REG(1),REG(2),REG(3),REG(4),REG(5)
3030 INPUT #1,HT,POWER,REF,SUM
3032 INPUT #1,EPS,SEARCH
3034 INPUT #1,DESEIG,EPSP
3036 FOR II=1 TO NREG
3040 INPUT #1,XC(II),RADIUS(II),THICK(II),PITCH(II)
3050 INPUT #1,RHOU(II),ENRICH(II),TS(II),TC(II)
3060 INPUT #1,TYPE(II),RHOC(II)
3070 INPUT #1,RHOW(II),TM(II)
3080 INPUT #1,STP(II),P(II),T0(II)
3110 INPUT #1,NC(II),NB(II),NBE(II)
3115 NEXT II
3116 IF REF<>0 THEN INPUT #1,NNB
3120 CLOSE #1  :  RETURN
3130 ' start sub correct data
3135 CLS : I=2   : LOCATE I,25 : PRINT "CORRECT DATA"
3140 I=I+2 : LOCATE I,5 : PRINT"[1] core data "
3150 I=I+2 : LOCATE I,5 : PRINT"[2] cell data "
3160 I=I+2 : LOCATE I,5 : PRINT"[3] fuel data "
3170 I=I+2 : LOCATE I,5 : PRINT"[4] clad data "
3180 I=I+2 : LOCATE I,5 : PRINT"[5] moderator data "
3190 I=I+2 : LOCATE I,5 : PRINT"[6] burnup data "
3200 I=I+2 : LOCATE I,5 : PRINT"[7] criticality data "
3210 I=I+2 : LOCATE I,5 : PRINT"[8] others data "
3220 I=I+2 : LOCATE I,5 : PRINT"[9] execute "
3230 LOCATE 23,5
3240 PRINT "enter index of data to be corrected [ ]";:LOCATE 23,42:INPUT"",INX
3250 IF INX=1 THEN CLS : GOSUB 3500: GOSUB 1500 :  GOTO 3130
3260 IF INX=2 THEN CLS : GOSUB 3500: GOSUB 1700 :  GOTO 3130
3270 IF INX=3 THEN CLS : GOSUB 3500: GOSUB 1900 :  GOTO 3130
```

```
3280 IF INX=4 THEN CLS : GOSUB 3500: GOSUB 2100 :  GOTO 3130
3290 IF INX=5 THEN CLS : GOSUB 3500: GOSUB 2200 :  GOTO 3130
3300 IF INX=6 THEN CLS : GOSUB 3500: GOSUB 2300 :  GOTO 3130
3310 IF INX=7 THEN CLS : GOSUB 3500: GOSUB 2400 :  GOTO 3130
3320 IF INX=8 THEN CLS : GOSUB 3500: GOSUB 2500 :  GOTO 3130
3330 IF INX=9 THEN RETURN
3340 BEEP : GOTO 3230
3345 '*** END OF SUB. CORRECT DATA
3500 LOCATE 22,25:PRINT"press RETURN if unchange" :RETURN
3600 LOCATE I,59 : COLOR 9,0 : PRINT A : LOCATE I,60 : INPUT"",X$ : IF X$<>""
     THEN A=VAL(X$) ELSE A=A
3605 COLOR 7
3610 RETURN
3700 PRINT"Do you want to correct data?(y/n): ":LOCATE I,40:PRINT"  ":
     LOCATE I,40: INPUT"", Y$
3710 RETURN
```

ข-12 รายละเอียดโปรแกรม PLINK.BAS

```
1    COMMON SUM,NREG,REF
2    COMMON FL$,OFL$
3    P$="PROGRAM EXECUTION" : TX$(1)=" to start execution":R$="RETUEN":PP$=
     "PROGRAM RUNNING.."
4    TX$(2)=" to terminate your job":E$="ESC"
20   IF FL$="" THEN FL$="B:FARCON.EXE"            : OFL$="FARCON.OUT" :
     T=1    : GOTO 70
30   IF FL$="B:FARCON.EXE" THEN FL$="B:SLOCON.EXE" : OFL$="SLOCON.OUT" :
     T=9    : GOTO 70
40   IF FL$="B:SLOCON.EXE" THEN FL$="B:ODMUG.EXE"  : OFL$="ODMUG.OUT"  :
     T=4    : GOTO 70
50   IF FL$="B:ODMUG.EXE" THEN FL$="B:FBURN.EXE"   : OFL$="FBURN.OUT"  :
     T=1    : GOTO 70
60   IF FL$="B:FBURN.EXE" THEN GOSUB 500

70   CLS  '
80   LOCATE 5,25:COLOR 15,0:PRINT CHR$(201);STRING$(23,205);CHR$(187)
85   LOCATE 6,25:PRINT CHR$(186);SPC(23);CHR$(186)
90   LOCATE 7,25:PRINT CHR$(186);"   ";P$;"   ";CHR$(186)
95   LOCATE 8,25:PRINT CHR$(186);SPC(23);CHR$(186)
100  LOCATE 9,25:PRINT CHR$(200);STRING$(23,205);CHR$(188):COLOR 7,0
110  LOCATE 15,15:PRINT "press ";:color 15,0:print R$;:COLOR 7,0:PRINT TX$(1)
120  LOCATE 17,15:PRINT "or press ";:color 15,0:print E$;:COLOR 7,0:PRINT TX$(2)
130  A$=INPUT$(1)
140  IF A$=CHR$(13) THEN GOSUB 200 : GOTO 170
```

```
150 IF A$=CHR$(27) THEN SYSTEM
160 BEEP : GOTO 130
200 LOCATE 7,29:COLOR 31,0 : PRINT PP$ :COLOR 7,0
210 TIM=T*(NREG+SUM+REF)
215 LOCATE 15,15:COLOR 0,0:PRINT "press ";R$;TX$(1)
220 LOCATE 17,15:PRINT "or press ";E$;TX$(2):COLOR 7,0
230 LOCATE 22,50:COLOR 15,0:PRINT "Wait about ";TIM;" minutes":COLOR 7,0
240 SHELL FL$
250 CHAIN "PRIN.BAS"
500 CLS : LOCATE 10,25
510 COLOR 31,0 :PRINT"EXECUTION COMPLETE" : COLOR 7,0
520 LOCATE 21,15:PRINT"Would you like to continue execution"
530 LOCATE 22,15:PRINT"for the next core life (y/n)? :"
540 A$=INPUT$(1)
550 IF A$="Y" OR A$="y" THEN CHAIN "NEWVER.BAS"
560 CLS :COLOR 15,0 : PRINT "End of job" : COLOR 7,0
570 SYSTEM
```

ข-13 รายละเอียดโปรแกรม PRIN.BAS

```
1   COMMON SUM,NREG,REF
2   COMMON FL$,OFL$
10  CLS
12  P1$="[1] PRINT OUTPUT ON ":P2$="[2] PRINT OUTPUT ON "
14  S$="SCREEN "   : P$="PRINTER" :M$="              PRINT MENU              "
16  E1$="[3] EXECUTE THE NEXT PROGRAM"
18  E2$="    OR TERMINATE YOUR JOB    "
20  LOCATE 5,20:COLOR 15,0:PRINT CHR$(201);STRING$(36,205);CHR$(187)
25  LOCATE 6,20:PRINT CHR$(186);:COLOR 15,0:PRINT M$;CHR$(186)
30  LOCATE 7,20:PRINT CHR$(186);STRING$(36," ");CHR$(186):COLOR 7,0
40  LOCATE 8,20:COLOR 15,0:PRINT CHR$(186);"    ";:COLOR 7,0:PRINT P1$;:COLOR
    15,0:PRINT S$;"     ";CHR$(186):COLOR 7,0
50  LOCATE 9,20:COLOR 15,0:PRINT CHR$(186);"    ";:COLOR 7,0:PRINT P2$;:COLOR
    15,0:PRINT P$;"     ";CHR$(186):COLOR 7,0
55  LOCATE 10,20:COLOR 15,0:PRINT CHR$(186);"    ";:COLOR 7,0:PRINT E1$;
    "    ";:COLOR 15,0:PRINT CHR$(186):COLOR 7,0
56  LOCATE 11,20:COLOR 15,0:PRINT CHR$(186);"    ";:COLOR 7,0:PRINT E2$;
    "    ";:COLOR 15,0:PRINT CHR$(186):COLOR 7,0
60  LOCATE 12,20:COLOR 15,0:PRINT CHR$(186);STRING$(36," ");CHR$(186)
70  LOCATE 13,20:PRINT CHR$(200);STRING$(36,205);CHR$(188):COLOR 7,0
80  LOCATE 15,35:PRINT "Selected number --->"
90  A$=INPUT$(1)
100 LOCATE 15,57:PRINT A$
110 IF A$="1" THEN FIL2$=OFL$ : GOSUB 500
```

```
120 IF A$="3" THEN CHAIN "PLINK.BAS"
130 IF A$<>"2" THEN BEEP: GOTO 90
140 SHELL "COPY OFL$ LPT1:"
150 CHAIN "PRIN.BAS"
500 DIM A$(1000)
520 OPEN FIL2$ FOR INPUT AS #1
530 I=0
540 IF EOF(1) THEN N=I : GOTO 580
550 I=I+1
560 LINE INPUT #1,A$(I)
570 GOTO 540
580 A=1 : B=15
590  CLS  :  II=4
600 IF B>N THEN B=N : GOTO 610
610 FOR I=A TO B  : II=II+1
620 LOCATE II,1 : PRINT A$(I)
630 NEXT I
640 LOCATE 22,1 : PRINT STRING$(80,CHR$(22))
650 LOCATE 23,5 : PRINT "  (GREY)+ = NEXT PAGE      (GREY)- = PREVIOUS PAGE
    Return = EXIT"
660 B$=INPUT$(1)
670 IF B$=CHR$(13) THEN CLOSE : CHAIN "PRIN.BAS"
680 IF B$=CHR$(43) THEN 750
690 IF B$=CHR$(45) THEN 760
700 BEEP : GOTO 660
710 BEEP :CLS:COLOR 0,7:PRINT "ERROR":COLOR 7,0 : CHAIN "PRIN.BAS"
750 IF B=N THEN 700 ELSE A=B :B=B+14 : GOTO 590
760 IF A=1 THEN 700 ELSE B=A : A=A-14 : GOTO 590
```

ภาคผนวก ค

ค-1 รายละเอียดผลลัพธ์จากมอดูล FARCON

```
     TITLE   "test
-                          VOLUME FRACTIONS
     FUEL =  .301      CLAD =  .136      MODERATOR=  .562
-                        FUEL TEMPERATURES (KELVIN)
                    SURFACE =  563.0       CENTER = 1126.0
-     ENRICHMENT =  .0360       ROD RADIUS =  .455 (CM.)
      UO2 DENSITY =  9.92(G/CC)

     HEXAGONAL LATTICE

     RESONANCE INTEGRAL = 23.43
```

INDEX	NAME	NUMBER DENSITIES (BARN-CM)**-1
1	ZIRCONIUM-2	.55871E-02
2	HYDROGEN	.28248E-01
3	OXYGEN	.27470E-01
4	BERYLLIUM	.00000E+00
5	BORON-10	.00000E+00
6	CARBON	.00000E+00
7	S.S.-304	.00000E+00
8	U-235	.24023E-03
9	U-236	.00000E+00
10	U-238	.64192E-02
11	PU-239	.00000E+00
12	PU-240	.00000E+00
13	PU-241	.00000E+00
14	PU-242	.00000E+00

```
     BUCKLING =    .3310E-02
```

MICROGROUP	FLUX	RES. ESCAPE PROB.
1	.12635E+00	1.000
2	.70811E+00	1.000
3	.16477E+01	1.000
4	.23813E+01	1.000
5	.25908E+01	1.000

6	.24250E+01	1.000
7	.21322E+01	1.000
8	.18081E+01	1.000
9	.15337E+01	1.000
10	.13058E+01	1.000
11	.11091E+01	1.000
12	.96531E+00	1.000
13	.86952E+00	1.000
14	.80651E+00	1.000
15	.76425E+00	1.000
16	.73323E+00	1.000
17	.71252E+00	1.000
18	.70223E+00	1.000
19	.69626E+00	.998
20	.68137E+00	.976
21	.66474E+00	.998
22	.65298E+00	.991
23	.63713E+00	.989
24	.62264E+00	.991
25	.61152E+00	1.000
26	.59346E+00	.973
27	.56758E+00	.970
28	.54927E+00	1.000
29	.52061E+00	.926
30	.49529E+00	1.000
31	.49040E+00	1.000
32	.50734E+00	1.000
33	.50805E+00	1.000

	D	ABSORTION	ELASTIC REMOVAL	MACROGROUP FLUX
FAST	1.663	.27162E-02	.39044E-01	.21174E+02
RESONANCE	.820	.20660E-01	.52146E-01	.10947E+02

	NUFISSION	KAPPA FSN.
FAST	.32450E-02	.37112E-13
RESONANCE	.11801E-01	.15152E-12

ค-2 รายละเอียดผลลัพธ์จากมอดูล SLOCON

TITLE "Test

**** SLOWCON INPUT DATA ****

THE BUCKLING IS .00331000 CM-2

THE TEMPERATURE IS 550.00 DEGREES KELVIN

ELEMENT	#	MOLECULAR WEIGHT	RHO	VOLUME FRACTION	NUMBER DENSITY
HYDROGEN	1	18.00	.751	.56208	.02823
OXYGEN	2	1.00	1.000	.04560	.02745
FP Pu239	3	110.00	.000	.00000	.00000
CARBON	4	12.00	.000	.00000	.00000
Pu-240	5	240.00	.000	.00000	.00000
U-238	6	270.00	9.925	.29059	.00643
Pu-242	7	242.00	.000	.00000	.00000
U-235	8	270.00	9.925	.01085	.00024
U-236	9	236.00	.000	.00000	.00000
Pu-239	10	239.00	.000	.00000	.00000
Pu-241	11	241.00	.000	.00000	.00000
Xe-135	12	135.00	.000	.00000	.00000
Sm-149	13	149.00	.000	.00000	.00000
ZIRC-2	14	90.00	6.500	.13648	.00593
SS-304	15	60.00	.000	.00000	.00000
BORON-10	16	10.00	.000	.00000	.00000
FP U235	17	110.00	.000	.00000	.00000

THE ENERGY INCREMENT IS .0100 EV

OUTPUT OF THE SLOWCON CODE

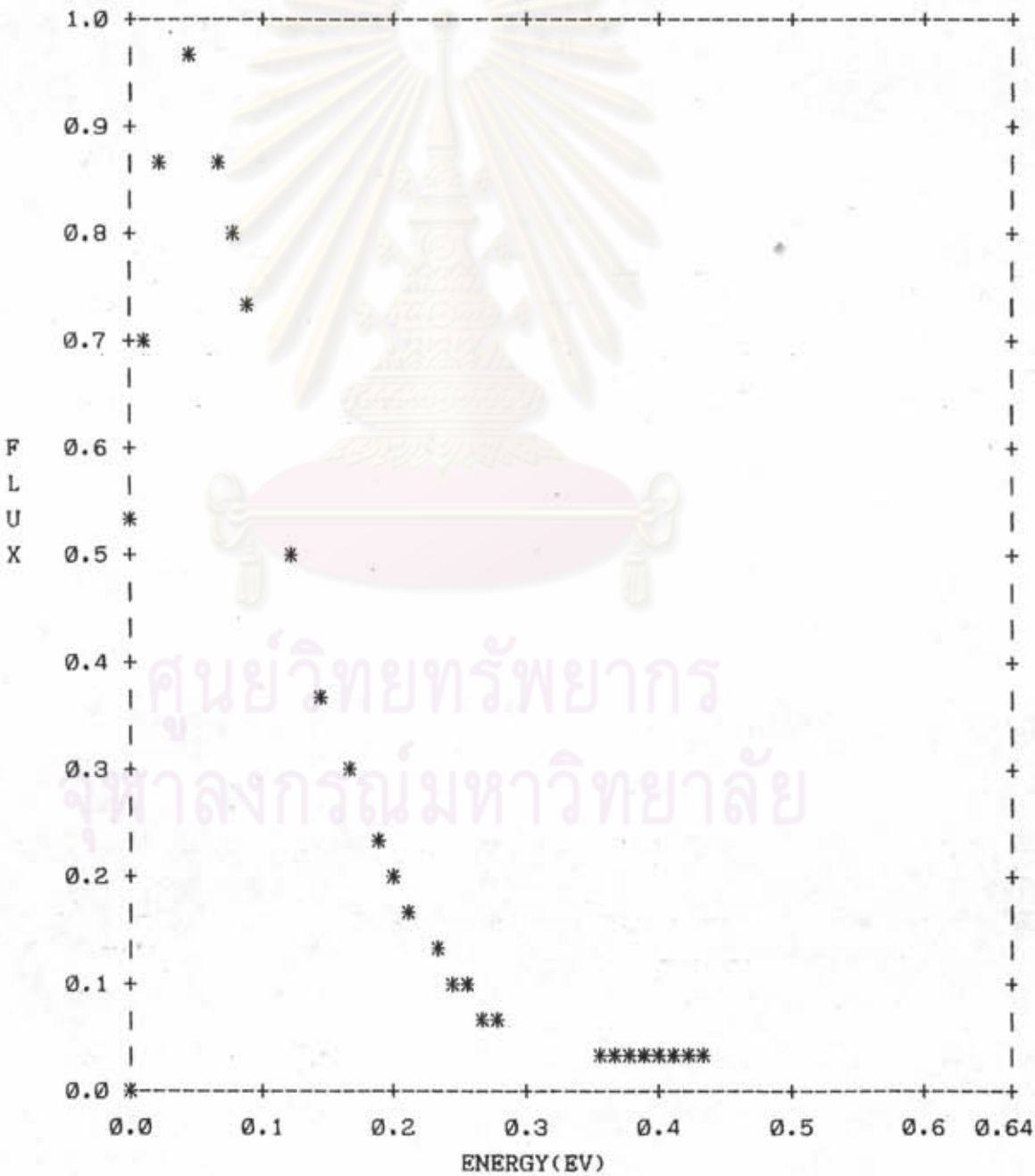
RUNGE KUTTA SOLUTION OF THE WIGNER-WILKINS EQUATION

ENERGY	J	FLUX
.0100	-.7495E-01	.4753E-02
.0200	-.3231E+00	.6562E-02
.0300	-.5322E+00	.8189E-02
.0400	-.7159E+00	.8935E-02
.0500	-.8811E+00	.9032E-02
.0600	-.1017E+01	.8669E-02
.0700	-.1085E+01	.8068E-02
.0800	-.1143E+01	.7388E-02
.0900	-.1192E+01	.6660E-02
.1000	-.1233E+01	.5956E-02
.1100	-.1265E+01	.5278E-02
.1200	-.1291E+01	.4663E-02
.1300	-.1309E+01	.4097E-02
.1400	-.1320E+01	.3601E-02
.1500	-.1325E+01	.3157E-02
.1600	-.1325E+01	.2774E-02

.1700	-.1318E+01	.2435E-02
.1800	-.1306E+01	.2146E-02
.1900	-.1288E+01	.1892E-02
.2000	-.1266E+01	.1675E-02
.2100	-.1238E+01	.1485E-02
.2200	-.1206E+01	.1322E-02
.2300	-.1169E+01	.1179E-02
.2400	-.1128E+01	.1055E-02
.2500	-.1082E+01	.9455E-03
.2600	-.1032E+01	.8505E-03
.2700	-.9866E+00	.7646E-03
.2800	-.9756E+00	.6881E-03
.2900	-.9596E+00	.6126E-03
.3000	-.9394E+00	.5566E-03
.3100	-.9151E+00	.5050E-03
.3200	-.8870E+00	.4602E-03
.3300	-.8551E+00	.4190E-03
.3400	-.8194E+00	.3833E-03
.3500	-.7802E+00	.3504E-03
.3600	-.7374E+00	.3221E-03
.3700	-.6913E+00	.2960E-03
.3800	-.6420E+00	.2736E-03
.3900	-.5896E+00	.2528E-03
.4000	-.5342E+00	.2350E-03
.4100	-.4759E+00	.2186E-03
.4200	-.4149E+00	.2045E-03
.4300	-.3514E+00	.1914E-03
.4400	-.2854E+00	.1803E-03
.4500	-.2171E+00	.1699E-03
.4600	-.1467E+00	.1612E-03
.4700	-.7439E-01	.1530E-03
.4800	-.2126E-03	.1462E-03
.4900	.7563E-01	.1398E-03
.5000	.1530E+00	.1346E-03
.5100	.2317E+00	.1297E-03
.5200	.3116E+00	.1258E-03
.5300	.3926E+00	.1221E-03
.5400	.4745E+00	.1193E-03
.5500	.5571E+00	.1166E-03
.5600	.6403E+00	.1148E-03
.5700	.7240E+00	.1131E-03
.5800	.8081E+00	.1122E-03
.5900	.8923E+00	.1113E-03
.6000	.9767E+00	.1112E-03
.6100	.1012E+01	.1110E-03

```
              .6200    .1049E+01    .1111E-03
              .6300    .1015E+01    .1111E-03
              .6400    .1057E+01    .1109E-03
          $$$GROUP CONSTANTS$$$
THE AVERAGE DIFFUSION COEFFICIENT IS       .350386
THE AVERAGE MARCRSCOPIC ABSORPTION CROSS SECTION IS              .106480
THE AVERAGE NU*SIGMA FISSION IS        .18935120
THE AVERAGE SIGMA FISSION IS        .07792230
THE AVERAGE FLUX IS    .1872E-02
THE AVERAGE POWER DENSITY IS    .4673E-14  WATTS/CC

1                              PLOT OF FLUX VS ENERGY
```



ค-3 รายละเอียดผลลัพธ์จากมอดูล DISFAC

TITLE "TEST FOR ORIGINAL"

INPUT

LATTICE ARRANGMENT IS HEXAGONAL

RADIUS OF FUEL ROD	.37750
CENTER TO CENTER DISTANCE	1.80956
MODERATOR ABSORPTION CROSS SECTION	.00858
MODERATOR SCATTERING CROSS SECTION	1.39150
FUEL ABSOPTION CROSS SECTION	.30520
FUEL SCATTERING CROSS SECTION	.64210
FUEL FISSION CROSS SECTION	.23285
FUEL DIFFUSION CONSTANT	.35185
MODERATOR DIFFUSION CONSTANT	.29962

OUTPUT

VOLUME RATIO (MODERATOR TO FUEL)	5.33422
THERMAL UTILIZATION	.85503
DISADVATAGE FACTOR	1.13060

HOMOGENIZED PROPERTIES

ABSORPTION CROSS SECTION	.05077
DIFFUSION CONSTANT	.30730
FISSION CROSS SECTION	.03312

ค-4 รายละเอียดผลลัพธ์จากมอดูล ODOG

TITLE "TEST FOR ORIGINAL"

RADII SEPARATING EACH REGION
50.000 78.000

DIFFUSION CONSTANT IN EACH REGION
7.400 2.120
ABSORPTION CROSS SECTION IN EACH REGION
.590 .070

NU*FISSION CROSS SECTION IN EACH REGION
.698 .110

CYLINDRICAL GEOMETRY

NUMBER OF INTERVALS IN EACH REGION
20 20

SIZE OF INTERVAL IN EACH REGION
2.564 1.400

SUB-DIAGONAL	DIAGONAL	SUPER-DIAGONAL	SOURCE TERM
.000E+00	.942E+01	-.740E+01	.229E+01
-.740E+01	.283E+02	-.148E+02	.688E+01
-.148E+02	.471E+02	-.222E+02	.115E+02
-.222E+02	.659E+02	-.296E+02	.161E+02
-.296E+02	.848E+02	-.370E+02	.207E+02
-.370E+02	.104E+03	-.444E+02	.252E+02
-.444E+02	.122E+03	-.518E+02	.298E+02
-.518E+02	.141E+03	-.592E+02	.344E+02
-.592E+02	.160E+03	-.666E+02	.390E+02
-.666E+02	.179E+03	-.740E+02	.436E+02
-.740E+02	.198E+03	-.814E+02	.482E+02
-.814E+02	.217E+03	-.888E+02	.528E+02
-.888E+02	.235E+03	-.962E+02	.574E+02
-.962E+02	.254E+03	-.104E+03	.620E+02
-.104E+03	.273E+03	-.111E+03	.665E+02
-.111E+03	.292E+03	-.118E+03	.711E+02
-.118E+03	.311E+03	-.126E+03	.757E+02
-.126E+03	.330E+03	-.133E+03	.803E+02
-.133E+03	.349E+03	-.141E+03	.849E+02
-.141E+03	.259E+03	-.768E+02	.486E+02
-.768E+02	.161E+03	-.789E+02	.792E+01
-.789E+02	.166E+03	-.810E+02	.813E+01
-.810E+02	.170E+03	-.831E+02	.835E+01
-.831E+02	.174E+03	-.853E+02	.856E+01
-.853E+02	.179E+03	-.874E+02	.878E+01
-.874E+02	.183E+03	-.895E+02	.899E+01
-.895E+02	.188E+03	-.916E+02	.921E+01
-.916E+02	.192E+03	-.937E+02	.942E+01
-.937E+02	.196E+03	-.959E+02	.964E+01
-.959E+02	.201E+03	-.980E+02	.986E+01
-.980E+02	.205E+03	-.100E+03	.101E+02
-.100E+03	.210E+03	-.102E+03	.103E+02

-.102E+03	.214E+03	-.104E+03	.105E+02
-.104E+03	.218E+03	-.106E+03	.107E+02
-.106E+03	.223E+03	-.109E+03	.109E+02
-.109E+03	.227E+03	-.111E+03	.111E+02
-.111E+03	.231E+03	-.113E+03	.114E+02
-.113E+03	.236E+03	-.115E+03	.116E+02
-.115E+03	.240E+03	-.117E+03	.118E+02

166 IS THE NUMBER OF OUTER ITERATIONS

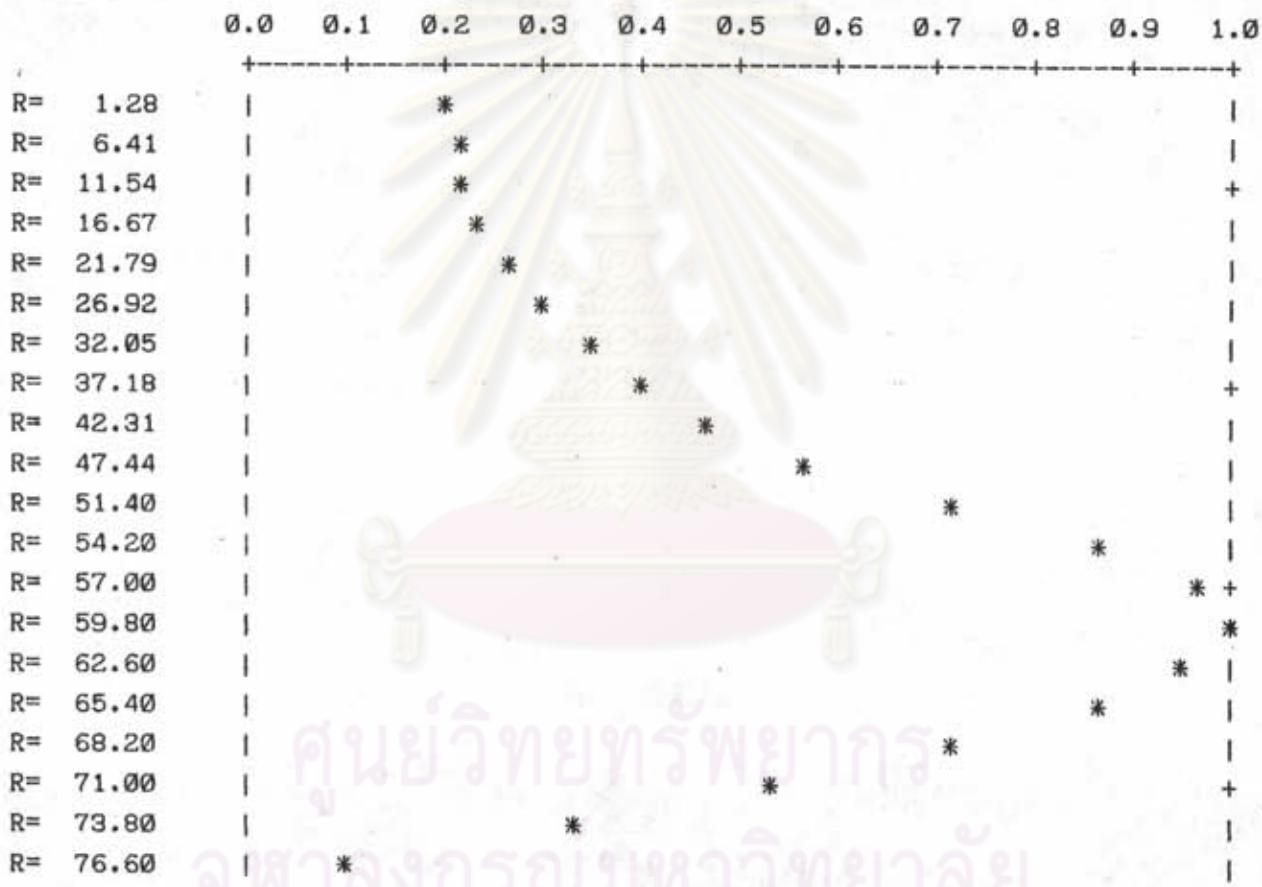
NORMALIZED FLUX IS GIVEN BELOW

1.2821	.2140
3.8462	.2155
6.4103	.2186
8.9744	.2233
11.5385	.2296
14.1026	.2376
16.6667	.2474
19.2308	.2591
21.7949	.2729
24.3590	.2888
26.9231	.3070
29.4872	.3278
32.0513	.3514
34.6154	.3780
37.1795	.4079
39.7436	.4415
42.3077	.4792
44.8718	.5213
47.4359	.5684
50.0000	.6209
51.4000	.7205
52.8000	.8062
54.2000	.8768
55.6000	.9319
57.0000	.9708
58.4000	.9935
59.8000	1.0000
61.2000	.9905
62.6000	.9656
64.0000	.9260
65.4000	.8726
66.8000	.8065

68.2000	.7290
69.6000	.6416
71.0000	.5458
72.4000	.4432
73.8000	.3356
75.2000	.2246
76.6000	.1122

THE EIGENVALUE IS GIVEN BELOW

1.1667



ค-4 รายละเอียดผลลัพธ์จากมอดูล ODMUG

TITLE TEST FOR ORIGINAL

NO. GRPS= 3 BCL= 2 BCR= 1 GEOM= 1.00 NRGNS= 4 EPS= .100E-03

POWER = 4.400E+08 HEIGTH = 250.00

REG	GRP	D	SIG-A	SIG-R	NU*SIG-F
1	1	.1679E+01	.2476E-02	.3597E-01	.2674E-02
1	2	.8580E+00	.1593E-01	.4914E-01	.5197E-02
1	3	.3604E+00	.5779E-01	.0000E+00	.8578E-01
2	1	.1680E+01	.2567E-02	.3589E-01	.2882E-02
2	2	.8540E+00	.1741E-01	.4831E-01	.7767E-02
2	3	.3560E+00	.7755E-01	.0000E+00	.1277E+00
3	1	.1682E+01	.2709E-02	.3577E-01	.3205E-02
3	2	.8480E+00	.1970E-01	.4706E-01	.1173E-01
3	3	.3504E+00	.1065E+00	.0000E+00	.1893E+00
4	1	.7270E+00	.6039E-03	.2524E+00	.0000E+00
4	2	.2780E+00	.1032E-02	.1561E+00	.0000E+00
4	3	.1548E+00	.1878E-01	.1561E+00	.0000E+00

REG	GRP	NU	SIG-P	BUCKLING
1	1	.2623E+01	.0000E+00	.3310E-02
1	2	.2434E+01	.0000E+00	.3310E-02
1	3	.2439E+01	.0000E+00	.3310E-02
2	1	.2623E+01	.0000E+00	.3310E-02
2	2	.2434E+01	.0000E+00	.3310E-02
2	3	.2439E+01	.0000E+00	.3310E-02
3	1	.2623E+01	.0000E+00	.3310E-02
3	2	.2434E+01	.0000E+00	.3310E-02
3	3	.2439E+01	.0000E+00	.3310E-02
4	1	.0000E+00	.0000E+00	.3310E-02
4	2	.0000E+00	.0000E+00	.3310E-02
4	3	.0000E+00	.0000E+00	.3310E-02

REG	THICKNESS	NO. PTS.
1	82.41	10
2	38.89	10
3	22.89	10
4	55.00	10

COMPUTATION CONVERGED AFTER 23 ITERATIONS

KEFF= 1.04553

THE NORMALIZED CONVERGED FLUXES
(FLUX/MAXIMUM AVE. GROUP FLUX)

	1 GROUP	2 GROUP	3 GROUP
1	.3163551E+00	.1699078E+00	.1424868E+00
2	.3221796E+00	.1730361E+00	.1451103E+00
3	.3399394E+00	.1825748E+00	.1531096E+00
4	.3706258E+00	.1990563E+00	.1669314E+00
5	.4159466E+00	.2233978E+00	.1873448E+00
6	.4784369E+00	.2569611E+00	.2154916E+00
7	.5616153E+00	.3016376E+00	.2529567E+00
8	.6702038E+00	.3599739E+00	.3018501E+00
9	.8104692E+00	.4353810E+00	.3646788E+00
10	.9915891E+00	.5325668E+00	.4408512E+00
11	.1241047E+01	.6567034E+00	.4794522E+00
12	.1376048E+01	.7146382E+00	.4519510E+00
13	.1472137E+01	.7631121E+00	.4694583E+00
14	.1544096E+01	.8004446E+00	.4899882E+00
15	.1594669E+01	.8267543E+00	.5056511E+00
16	.1624594E+01	.8423204E+00	.5150815E+00
17	.1634414E+01	.8474553E+00	.5181302E+00
18	.1624835E+01	.8425419E+00	.5146999E+00
19	.1597067E+01	.8280525E+00	.5036520E+00
20	.1554458E+01	.8043572E+00	.4781449E+00
21	.1511040E+01	.7700779E+00	.4025494E+00
22	.1475133E+01	.7413560E+00	.3424231E+00
23	.1409402E+01	.7058545E+00	.3126027E+00
24	.1323949E+01	.6629602E+00	.2897247E+00
25	.1222566E+01	.6132364E+00	.2670787E+00
26	.1107057E+01	.5578131E+00	.2432053E+00
27	.9782835E+00	.4984642E+00	.2186875E+00
28	.8359060E+00	.4381645E+00	.1958082E+00
29	.6769774E+00	.3824148E+00	.1800913E+00
30	.4923329E+00	.3421937E+00	.1852292E+00
31	.2574837E+00	.3405650E+00	.2471556E+00
32	.2014157E-01	.4649085E-01	.4592976E-01
33	.1576613E-02	.4657865E-02	.5174716E-02
34	.1234880E-03	.4171399E-03	.4922390E-03
35	.9677753E-05	.3537915E-04	.4320130E-04
36	.7588546E-06	.2912343E-05	.3629545E-05
37	.5953357E-07	.2355863E-06	.2973102E-06
38	.4672735E-08	.1885670E-07	.2398538E-07
39	.3669079E-09	.1499475E-08	.1916892E-08
40	.2864131E-10	.1180080E-09	.1513420E-09

41	.0000000E+00	.0000000E+00	.0000000E+00

RELATIVE POINT GROUP AVERAGES

1	.2095832E+00
2	.2134420E+00
3	.2252080E+00
4	.2455378E+00
5	.2755631E+00
6	.3169632E+00
7	.3720699E+00
8	.4440093E+00
9	.5368430E+00
10	.6550024E+00
11	.7924008E+00
12	.8475459E+00
13	.9015691E+00
14	.9448428E+00
15	.9756916E+00
16	.9939988E+00
17	.1000000E+01
18	.9940256E+00
19	.9762571E+00
20	.9456534E+00
21	.8945559E+00
22	.8529706E+00
23	.8092863E+00
24	.7588781E+00
25	.7009604E+00
26	.6360250E+00
27	.5651451E+00
28	.4899596E+00
29	.4131612E+00
30	.3399186E+00
31	.2817348E+00
32	.3752073E-01
33	.3803064E-02
34	.3442890E-03
35	.2941940E-04
36	.2433581E-05
37	.1974767E-06
38	.1583827E-07
39	.1261091E-08
40	.9933043E-10

41 .0000000E+00

POINTWISE RELATIVE SOURCE (POWER) VALUES

POINT NO.	SOURCE (POWER)
1	.2576986E-03
2	.2099542E-02
3	.4430537E-02
4	.7245677E-02
5	.1084218E-01
6	.1558873E-01
7	.2195855E-01
8	.3057005E-01
9	.4221428E-01
10	.5749574E-01
11	.5914109E-01
12	.4910802E-01
13	.5352654E-01
14	.5831846E-01
15	.6267822E-01
16	.6638327E-01
17	.6932756E-01
18	.7140997E-01
19	.7240251E-01
20	.7134096E-01
21	.5878182E-01
22	.4816619E-01
23	.4512547E-01
24	.4268517E-01
25	.4007173E-01
26	.3711214E-01
27	.3388456E-01
28	.3070060E-01
29	.2833456E-01
30	.2873503E-01
31	.1845823E-01
32	.0000000E+00
33	.0000000E+00
34	.0000000E+00
35	.0000000E+00
36	.0000000E+00
37	.0000000E+00
38	.0000000E+00
39	.0000000E+00

40	.0000000E+00
41	.0000000E+00

RELATIVE SOURCE (POWER)

	1 GROUP	2 GROUP	3 GROUP
1	.1562429E-04	.1630932E-04	.2257650E-03
2	.1272953E-03	.1328765E-03	.1839370E-02
3	.2686225E-03	.2804010E-03	.3881513E-02
4	.4393028E-03	.4585660E-03	.6347807E-02
5	.6573551E-03	.6861819E-03	.9498643E-02
6	.9451316E-03	.9865819E-03	.1365702E-01
7	.1331324E-02	.1389724E-02	.1923750E-01
8	.1853510E-02	.1934894E-02	.2678165E-01
9	.2561611E-02	.2674510E-02	.3697816E-01
10	.3525813E-02	.3680438E-02	.5028949E-01
11	.3652012E-02	.4257844E-02	.5123124E-01
12	.2895892E-02	.4053742E-02	.4215838E-01
13	.3237733E-02	.4523788E-02	.4576502E-01
14	.3542441E-02	.4949728E-02	.4982629E-01
15	.3809714E-02	.5323771E-02	.5354473E-01
16	.4035287E-02	.5639337E-02	.5670865E-01
17	.4214692E-02	.5890359E-02	.5922250E-01
18	.4344101E-02	.6071607E-02	.6099426E-01
19	.4421331E-02	.6178873E-02	.6180230E-01
20	.4450807E-02	.6207690E-02	.6068246E-01
21	.3686425E-02	.5786701E-02	.4930869E-01
22	.2909439E-02	.5352453E-02	.3990430E-01
23	.2831268E-02	.5190501E-02	.3710370E-01
24	.2707965E-02	.4963714E-02	.3501349E-01
25	.2545251E-02	.4673411E-02	.3285307E-01
26	.2345212E-02	.4325624E-02	.3044130E-01
27	.2108144E-02	.3932035E-02	.2784438E-01
28	.1831858E-02	.3514950E-02	.2535379E-01
29	.1508300E-02	.3118860E-02	.2370740E-01
30	.1114897E-02	.2836585E-02	.2478355E-01
31	.2950637E-03	.1428609E-02	.1673456E-01
32	.0000000E+00	.0000000E+00	.0000000E+00
33	.0000000E+00	.0000000E+00	.0000000E+00
34	.0000000E+00	.0000000E+00	.0000000E+00
35	.0000000E+00	.0000000E+00	.0000000E+00
36	.0000000E+00	.0000000E+00	.0000000E+00
37	.0000000E+00	.0000000E+00	.0000000E+00
38	.0000000E+00	.0000000E+00	.0000000E+00
39	.0000000E+00	.0000000E+00	.0000000E+00

40	.0000000E+00	.0000000E+00	.0000000E+00
41	.0000000E+00	.0000000E+00	.0000000E+00

RELATIVE SOURCE (POWER) BY REGION AND GROUP

REG	GROUP	AVE. SOURCE
1	1	.16218E-02
2	1	.32994E-02
3	1	.18660E-02
4	1	.14213E-04
1	2	.17168E-02
2	2	.45917E-02
3	2	.35244E-02
4	2	.68816E-04
1	3	.23245E-01
2	3	.46190E-01
3	3	.26339E-01
4	3	.80611E-03

RELATIVE FLUX BY REGION AND GROUP

REG	GROUP	AVE. FLUX
1	1	.12677E-02
2	1	.28358E-02
3	1	.19186E-02
4	1	.30521E-04
1	2	.67973E-03
2	2	.14705E-02
3	2	.10101E-02
4	2	.44046E-04
1	3	.55966E-03
2	3	.90151E-03
3	3	.46952E-03
4	3	.34265E-04

TO NORMALIZE THE ABOVE FLUX TO .440E+03 MEGAWATTS IN CORE,
MULTIPLY BY 2.0511E+16

REGION	AVE. REGION FLUX /MAX AVE. GROUP FLUX	AVE.REGION FLUX /MAX AVE. REGION FLUX
1	.4548973E+00	.4814065E+00
2	.9449338E+00	.1000000E+01
3	.6166091E+00	.6525421E+00
4	.1974721E-01	.2089798E-01

POINTWISE NORMALIZED FLUX VALUES

	1 GROUP	2 GROUP	3 GROUP
1	.1192144E+14	.6402747E+13	.5369415E+13
2	.1214090E+14	.6520617E+13	.5468265E+13
3	.1281005E+14	.6880021E+13	.5769676E+13
4	.1396630E+14	.7501030E+13	.6290466E+13
5	.1567395E+14	.8418205E+13	.7059630E+13
6	.1802855E+14	.9682856E+13	.8120192E+13
7	.2116270E+14	.1136626E+14	.9531862E+13
8	.2525430E+14	.1356436E+14	.1137416E+14
9	.3053949E+14	.1640569E+14	.1374155E+14
10	.3736416E+14	.2006768E+14	.1661174E+14
11	.4676375E+14	.2474518E+14	.1806621E+14
12	.5185072E+14	.2692819E+14	.1702991E+14
13	.5547137E+14	.2875469E+14	.1768958E+14
14	.5818274E+14	.3016140E+14	.1846316E+14
15	.6008835E+14	.3115272E+14	.1905332E+14
16	.6121593E+14	.3173926E+14	.1940864E+14
17	.6158588E+14	.3193271E+14	.1952351E+14
18	.6122486E+14	.3174755E+14	.1939424E+14
19	.6017852E+14	.3120157E+14	.1897794E+14
20	.5857299E+14	.3030870E+14	.1801680E+14
21	.5693690E+14	.2901701E+14	.1516831E+14
22	.5558386E+14	.2793474E+14	.1290272E+14
23	.5310706E+14	.2659701E+14	.1177906E+14
24	.4988717E+14	.2498072E+14	.1091700E+14
25	.4606697E+14	.2310709E+14	.1006369E+14
26	.4171453E+14	.2101872E+14	.9164116E+13
27	.3686227E+14	.1878242E+14	.8240272E+13
28	.3149742E+14	.1651029E+14	.7378165E+13
29	.2550890E+14	.1440961E+14	.6785939E+13
30	.1855138E+14	.1289406E+14	.6979545E+13
31	.9702133E+13	.1283268E+14	.9312965E+13
32	.7589459E+12	.1751802E+13	.1730661E+13
33	.5940770E+11	.1755110E+12	.1949863E+12
34	.4653100E+10	.1571807E+11	.1854785E+11
35	.3646631E+09	.1333106E+10	.1627849E+10
36	.2859407E+08	.1097388E+09	.1367633E+09
37	.2243258E+07	.8877026E+07	.1120282E+08
38	.1760714E+06	.7105313E+06	.9037832E+06
39	.1382530E+05	.5650108E+05	.7222959E+05
40	.1079221E+04	.4446607E+04	.5702654E+04
41	.0000000E+00	.0000000E+00	.0000000E+00

ประวัติผู้เขียน

นาย ไตรภพ ผ่องสุวรรณ เกิดเมื่อวันที่ 22 กรกฎาคม 2501 ที่อำเภอหาดใหญ่ จังหวัดสงขลา จบการศึกษาระดับมัธยมจากโรงเรียนมหาวชิราวุธ จังหวัดสงขลา แล้วเข้าศึกษาต่อในคณะวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่ ได้รับปริญญาวิทยาศาสตร์บัณฑิตสาขาฟิสิกส์ ในปี พ.ศ. 2523 ต่อมาในปี พ.ศ. 2528 ได้เข้าศึกษาที่ภาควิชานิวเคลียร์เทคโนโลยี คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ประวัติการทำงาน ได้เข้ารับราชการในตำแหน่งอาจารย์ของภาควิชาฟิสิกส์ คณะวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่ ตั้งแต่ปี พ.ศ. 2524 เรื่อยมาจนถึงปัจจุบัน