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HELM - A COMPUTER CODE TO CALCULATE MACROSCOPIC CROSS SECTIONS FOR THE PDQ-4 COMPUTER CODE

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U. S. ATOMIC ENERGY COMMISSION
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HELM - A Computer Code to
Calculate Macroscopic Cross Sections
for the PDQ-4 Computer Code

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D. F. Sudborough
J. J. Barth

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CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION HELM	☐ → PRELIMINARY FINAL → ☒
<p>I. <u>PURPOSE</u></p> <p>To calculate macroscopic cross sections which are compatible with the PDQ-4 computer code, using microscopic cross section data from HELM cross section file tapes. The output of the program is available both in printed form and as cards punched in PDQ-4 format.</p> <p>II. <u>INTRODUCTION</u></p> <p>HELM calculates macroscopic cross sections which are compatible with the PDQ-4 computer code. Two options have been included in the program. The first option (Case 2) calculates macroscopic cross sections as normally defined for use in PDQ.^{1, 2} However, PDQ is a few-group code and does not allow for multigroup scattering. It has another disadvantage in that it can not account for (n, 2n) reactions. For these reasons, a second option (Case 3) has been included which attempts to correct the PDQ diffusion equations for multigroup scattering and (n, 2n) reactions by a suitable re-definition of the macroscopic cross sections. A third case of HELM output (Case 1) is simply a complete set of macroscopic sections which are used in the calculations of Cases 2 and 3. These are printed in the output for the convenience of the user. All three cases are discussed in detail in Section V.</p> <p>The input to HELM is supplied by two means:</p> <ol style="list-style-type: none">1. Punched cards containing the file name, input options, composition numbers, material numbers, atom densities, and flux ratios.2. A file tape containing the microscopic cross section data.		
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<p>Let us define:</p> <p>i = Neutron lethargy group number</p> <p>I = Maximum group number ($1 \leq I \leq 4$)</p> <p>j = Neutron source group ($j \geq i$)</p> <p>J = Maximum source group for inelastic scatter ($J \leq I$)</p> <p>m = Material designation number ($1 \leq m \leq 999$)</p> <p>M = Maximum material number for nonhydrogen materials</p> <p>k = Composition number ($1 \leq k \leq 100$)</p> <p>$N_{k,m}$ = Atom density of Material m in Composition k (in nuclei/cm-barn)</p> <p>κ = Power normalization factor</p> <p>$\left(\frac{\phi_1}{\phi_2}\right)_k, \left(\frac{\phi_1}{\phi_3}\right)_k, \left(\frac{\phi_2}{\phi_3}\right)_k$ = Average flux ratios for Composition k</p> <p>$\nu_{m,i}$ = Number of neutrons released per fission of Material m for Group i</p> <p>$(\sigma_x)_{m,i}$ = Microscopic cross section for Material m, Group i where $x = f$ denotes fission $x = c$ denotes capture $x = tr$ denotes transport $x = in$ denotes inelastic scatter $x = er$ denotes elastic scatter $x = sh$ denotes hydrogen scatter</p> <p>$(\sigma_{in})_{m,i-j}$ = Inelastic scattering cross section from Group i to j, for Material m</p> <p>ΔU_i = Lethargy width of Group i</p> <p>χ_i = Fraction of fission neutrons released into Group i</p>		
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III. CALCULATIONS

The set of equations necessary for the calculations is divided into three separate cases as described in the discussion. The results of the calculations of Case 1 are used for both Cases 2 and 3. However, both Cases 2 and 3 are independent of each other and either may or may not be run, depending on the input options. It is possible that both Cases 2 and 3 will be requested and both results supplied in the output.

A. Case 1

This case calculates those macroscopic cross sections having physical significance. The results of this case are printed in the output and stored for use by Cases 2 and 3.

$$D_{k,i} = \left[3 \sum_{m=1}^{999} N_{k,m} (\sigma_{tr})_{m,i} \right] \quad (1.1)$$

$$(\Sigma_c)_{k,i} = \sum_{m=1}^{999} N_{k,m} (\sigma_c)_{m,i} \quad (1.2)$$

$$(\Sigma_f)_{k,i} = \sum_{m=1}^{999} N_{k,m} (\sigma_f)_{m,i} \quad (1.3)$$

$$\bar{\nu}_{k,i} = \frac{\left[\sum_{m=1}^{999} N_{k,m} \nu_{i,m} (\sigma_f)_{m,i} \right]}{\Sigma_{f,k,i}} \quad (1.4)$$

$$(\Sigma_{er})_{k,i} = \sum_{m=1}^M N_{k,m} (\sigma_{er})_{m,i} \quad (1.5)$$

$$(\Sigma_{in})_{k,i} = \sum_{m=1}^M N_{k,m} (\sigma_{in})_{m,i} \quad (1.6)$$

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and the inelastic scattering matrix

$$(\Sigma_{in})_{k, i-j} = \sum_{m=1}^M N_{k, m} (\sigma_{in})_{m, i-j} \quad (1.7)$$

When hydrogen is present in Composition k, the following are calculated:

$$(\Sigma_{SG})_{k, i} = \sum_{m=M+1}^{999} N_{k, m} (\sigma_{SH})_{i, m} \left[\frac{1-e^{-\Delta U_i}}{\Delta U_i} \right] \quad (1.8)$$

and the hydrogen scattering matrix

$$(\Sigma_{SG})_{k, i-j} = (\Sigma_{SG})_{k, i} \left(1 - e^{-\Delta U_j} \right) \exp \left(- \sum_{\ell=i+1}^{j-1} \Delta U_{\ell} \right) \quad (1.9)$$

Equations 1.1 to 1.9 are calculated for each Composition k, and for all groups $1 \leq i \leq I$. Equations 1.7 and 1.9 are calculated for both $1 \leq i \leq I$ and $1 \leq j \leq I$. For Group I set

$$(\Sigma_{cr})_{k, I} = (\Sigma_{in})_{k, I} = (\Sigma_{SG})_{k, I} = 0$$

The equations used in Case 3 require complete four-group inelastic scattering and hydrogen scattering matrices, even when $I \leq 4$ or $J \leq I$. All values of these matrices not calculated by the above equations must exist in storage and be equal to zero.

If $J < I$ set

$$(\Sigma_{in})_{k, \ell-n} = 0 \quad \begin{matrix} 1 \leq \ell \leq 3 \\ J+1 \leq n \leq I, \text{ with } n > \ell \end{matrix} \quad (1.10)$$

And if $I < 4$ set

$$(\Sigma_{in})_{k, \ell-n} = (\Sigma_{SG})_{k, \ell-n} = 0 \quad \begin{matrix} 1 \leq \ell \leq 3 \\ I+1 \leq n \leq 4 \\ \text{with } n < \ell \end{matrix} \quad (1.11)$$

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<p>When hydrogen is not present in Composition k, the entire four-group hydrogen scattering matrix must exist and be set equal to zero. As above in Equation 1.11, this is true even when $I < 4$.</p> $(\Sigma_{SG})_{k, \ell-n} = 0 \quad \begin{matrix} 1 \leq \ell \leq 3 \\ \ell + 1 \leq n \leq 4 \end{matrix} \quad (1.12)$ <p>B. <u>Case 2</u></p> <p>This case calculates (when $\delta 2 = 1$) the macroscopic cross sections normally required for use in the PDQ-4 code. The output of this case is available both in printed form and as cards punched in PDQ-4 format. These calculations are dependent on the values previously calculated in Case 1.</p> $D_{k,i} = D_{k,i} \quad (2.1)$ $(\Sigma_a)_{k,i} = (\Sigma_c)_{k,i} + (\Sigma_f)_{k,i} \quad (2.2)$ $(\Sigma_R)_{k,i} = (\Sigma_{er})_{k,i} + (\Sigma_{SG})_{k,i} + \sum_{j=i+1}^J (\Sigma_{in})_{k,i-j} \quad (2.3)$ $(\bar{\nu}\Sigma_f)_{k,i} = \bar{\nu}_{k,i} (\Sigma_f)_{k,i} \quad (2.4)$ $(\kappa\Sigma_f)_{k,i} = \kappa (\Sigma_f)_{k,i} \quad (2.5)$ $\chi_{k,i} = \chi_i \quad (2.6)$ $(\Sigma_R)_{k,I} = 0 \quad (2.7)$ <p>These calculations are performed for all Compositions k, and for $1 \leq i \leq I$.</p> <p>C. <u>Case 3</u></p> <p>This case calculates (when $\delta 3 = 1$) a set of macroscopic cross sections and chi values which have been so defined as to compensate for multigroup scattering and for the presence of (n, 2n) materials in the composition. Two complete sets of equations have been defined which depend on whether or not the value of $\sum_i (\Sigma_f)_{k,i}$ is equal to zero for Composition k. These calculations are dependent on the values calculated by Case 1. The values calculated by this case have no physical significance and sometimes may even be negative. The results are available in both printed form and as cards punched in PDQ-4 format.</p>		
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<p>These calculations are performed for each Composition k and for $1 \leq i \leq I$.</p> <p>1. When $\sum_{i=1}^I (\Sigma_f)_{k,i} \neq 0$ for Composition k:</p> <p style="margin-left: 20px;">a. For $1 \leq i \leq I$</p> <div style="margin-left: 40px;"> $D_{k,i} = D_{k,i} \quad (3.1)$ $(\nu \Sigma_f)_{k,i} = \bar{\nu}_{k,i} (\Sigma_f)_{k,i} \quad (3.2)$ $(\kappa \Sigma_f)_{k,i} = \kappa (\Sigma_f)_{k,i} \quad (3.3)$ $\chi_{k,i} = \chi_i \quad (3.4)$ $(\Sigma_R)_{k,I} = 0 \quad (\text{regardless of value calculated below}) \quad (3.5)$ </div> <p style="margin-left: 20px;">b. When $i = 1$</p> <div style="margin-left: 40px;"> $(\Sigma_a)_{k,i} = \left[(\Sigma_c)_{k,1} + (\Sigma_f)_{k,1} + (\Sigma_{SG})_{k,1-3} + \Sigma_{SG \ k,1-4} \right. \\ \left. + (\Sigma_{in})_{k,1} - (\Sigma_{in})_{k,1-2} \right] \quad (3.6)$ $(\Sigma_R)_{k,i} = \left[(\Sigma_{SG})_{k,1-2} + (\Sigma_{in})_{k,1-2} + (\Sigma_{er})_{k,1} \right] \quad (3.7)$ </div> <p style="margin-left: 20px;">c. When $i = 2$</p> <div style="margin-left: 40px;"> $(\Sigma_a)_{k,i} = (\Sigma_c)_{k,2} + (\Sigma_f)_{k,2} + (\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2} - (\Sigma_{in})_{k,2-3} \\ - \left[(\Sigma_{SG})_{k,1-3} + (\Sigma_{in})_{k,1-3} \right] \left(\frac{\phi_1}{\phi_2} \right)_k \quad (3.8)$ </div>		
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$ \begin{aligned} (\Sigma_R)_{k,i} &= (\Sigma_{SG})_{k,2-3} + (\Sigma_{in})_{k,2-3} + (\Sigma_{er})_{k,2} \\ &\quad + \left[(\Sigma_{SG})_{k,1-3} + (\Sigma_{in})_{k,1-3} \right] \left(\frac{\phi_1}{\phi_2} \right)_k \end{aligned} \tag{3.9} $ <p>d. When $i = 3$</p> $ \begin{aligned} (\Sigma_a)_{k,i} &= (\Sigma_c)_{k,3} + (\Sigma_f)_{k,3} + (\Sigma_{in})_{k,3} - (\Sigma_{in})_{k,3-4} \\ &\quad - \left[(\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-4} \right] \left(\frac{\phi_1}{\phi_3} \right)_k \\ &\quad - \left[(\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2-4} \right] \left(\frac{\phi_2}{\phi_3} \right)_k \end{aligned} \tag{3.10} $ $ \begin{aligned} (\Sigma_R)_{k,i} &= (\Sigma_{SG})_{k,3-4} + (\Sigma_{in})_{k,3-4} + (\Sigma_{er})_{k,3} \\ &\quad + \left[(\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-4} \right] \left(\frac{\phi_1}{\phi_3} \right)_k \\ &\quad + \left[(\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2-4} \right] \left(\frac{\phi_2}{\phi_3} \right)_k \end{aligned} \tag{3.11} $ <p>e. When $i = 4$</p> $ (\Sigma_a)_{k,i} = (\Sigma_c)_{k,4} + (\Sigma_f)_{k,4} \tag{3.12} $ $ (\Sigma_R)_{k,i} = 0 \tag{3.13} $		
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<p>In the above equations, if the values of $\left(\frac{\phi_1}{\phi_2}\right)_k$, $\left(\frac{\phi_1}{\phi_3}\right)_k$, and $\left(\frac{\phi_2}{\phi_3}\right)_k$ are not supplied in the input for Composition k, they are assumed equal to one.</p> <p>2. When $\sum_{i=1}^I (\Sigma_f)_{k,i} = 0$ for Composition k:</p> <p>a. For $1 \leq i \leq 4$</p> <p>(1) When $i = 1$</p> <div style="text-align: right; margin-right: 50px;">(3.14)</div> $\chi_{k,i} = 0$ <p>(2) When $i = 2$</p> <div style="text-align: right; margin-right: 50px;">(3.15)</div> $\chi_{k,i} = 0$ <p>(3) When $i = 3$</p> <div style="text-align: right; margin-right: 50px;">(3.16)</div> $\chi_{k,i} = \frac{(\Sigma_{SG})_{k,1-3} + (\Sigma_{in})_{k,1-3}}{(\Sigma_{SG})_{k,1-3} + (\Sigma_{in})_{k,1-3} + (\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-4}}$ <p>(4) When $i = 4$</p> <div style="text-align: right; margin-right: 50px;">(3.17)</div> $\chi_{k,i} = \frac{(\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-4}}{(\Sigma_{SG})_{k,1-3} + (\Sigma_{in})_{k,1-3} + (\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-4}}$ <p>The values of $\chi_{k,i}$ for $1 \leq i \leq 4$ are calculated first because these values will be required in the following equations regardless of the value of I.</p>		
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<p>b. For $1 \leq i \leq I$</p> $D_{k,i} = D_{k,i} \quad (3.18)$ $\kappa(\Sigma_f)_{k,i} = \kappa(\Sigma_f)_{k,i} \quad (3.19)$ $(\Sigma_R)_{k,I} = 0 \quad (\text{regardless of what value may be calculated below}) \quad (3.20)$ <p>(1) In addition, when $i = 1$</p> $\begin{aligned} (\Sigma_a)_{k,i} &= (\Sigma_c)_{k,1} + (\Sigma_{SG})_{k,1-3} + (\Sigma_{SG})_{k,1-4} \\ &\quad + (\Sigma_{in})_{k,1} - (\Sigma_{in})_{k,1-2} \end{aligned} \quad (3.21)$ $(\Sigma_R)_{k,i} = (\Sigma_{SG})_{k,1-2} + (\Sigma_{in})_{k,1-2} + (\Sigma_{er})_{k,1} \quad (3.22)$ $(\nu \Sigma_f)_{k,i} = (\Sigma_{SG})_{k,1-3} + (\Sigma_{SG})_{k,1-4} + (\Sigma_{in})_{k,1-3} + (\Sigma_{in})_{k,1-4} \quad (3.23)$ <p>(2) When $i = 2$</p> $\begin{aligned} (\Sigma_a)_{k,i} &= (\Sigma_c)_{k,2} + (\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2} - (\Sigma_{in})_{k,2-3} \\ &\quad + \left(\frac{\chi_3}{\chi_4} \right) \left[(\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2-4} \right] \end{aligned} \quad (3.24)$ $\begin{aligned} (\Sigma_R)_{k,i} &= (\Sigma_{SG})_{k,2-3} + (\Sigma_{in})_{k,2-3} + (\Sigma_{er})_{k,2} \\ &\quad - \left(\frac{\chi_3}{\chi_4} \right) \left[(\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2-4} \right] \end{aligned} \quad (3.25)$ $(\nu \Sigma_f)_{k,i} = \frac{[(\Sigma_{SG})_{k,2-4} + (\Sigma_{in})_{k,2-4}]}{\chi_{k,4}} \quad (3.26)$		
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<p>(3) When $i = 3$</p> $(\Sigma_a)_{k,i} = (\Sigma_c)_{k,3} + (\Sigma_{in})_{k,3} - (\Sigma_{in})_{k,3-4} \quad (3.27)$ $(\Sigma_R)_{k,i} = (\Sigma_{SG})_{k,3-4} + (\Sigma_{in})_{k,3-4} + (\Sigma_{er})_{k,3} \quad (3.28)$ $(\nu\Sigma_f)_{k,i} = 0 \quad (3.29)$ <p>(4) When $i = 4$</p> $(\Sigma_a)_{k,i} = (\Sigma_c)_{k,4} \quad (3.30)$ $(\Sigma_R)_{k,i} = 0 \quad (3.31)$ $(\nu\Sigma_f)_{k,i} = 0 \quad (3.32)$ <p>In Equations 3.16, 3.17, 3.24, 3.25, and 3.26, care must be taken to prevent division by zero. Whenever the denominator of the terms involved is equal to zero, the entire term is set equal to zero and the remaining calculation is unchanged.</p>		
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<p>IV. INPUT SUPPLIED</p> <p>A. From HELM File Tape (Format described in Section IV-F)</p> <div style="margin-left: 40px;"> <p>I = Number of lethargy group in the file ($1 \leq I \leq 4$)</p> <p>J = Largest group number having inelastic source in the file ($1 \leq J \leq 4$)</p> <p>χ_i = Fraction of neutrons released by fission into Group i.</p> <p>ΔU_i = Width of lethargy Group i</p> <p>$(\sigma_{in})_{m,i-j}$ = Inelastic scattering cross section from Group i to Group j, for Material m.</p> <p>$(\sigma_x)_{m,i}$ = Cross section for Group i, Material m, where $x = c$ refers to capture $x = f$ refers to fission $x = tr$ refers to transport $x = er$ refers to elastic removal $x = in$ refers to inelastic (total) $x = sh$ refers to hydrogen scattering</p> <p>$\nu_{m,i}$ = Neutrons released per fission for material m, group i.</p> </div> <p>B. Input Options - Information Supplied on Cards</p> <div style="margin-left: 40px;"> <p>1. f File name</p> <p>2. K Power normalization factor; if not supplied, it is assumed equal to 1.</p> <p>3. $\delta PR1$ = 0, Do not print results of Case 1. = 1, Print results of Case 1.</p> <p>4. $\delta 2$ = 0, Do not calculate Case 2. = 1, Calculate Case 2.</p> <p>5. $\delta 3$ = 0, Do not calculate Case 3. = 1, Calculate Case 3.</p> </div>		
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COMPUTATION AND DATA PROCESSING

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION	☐ PRELIMINARY ☒ FINAL																						
<p>C. Input Quantities - Information Supplied on Cards</p> <p>1. Set 1</p> <p style="margin-left: 40px;"> k = Composition number ($1 \leq k \leq 100$) m = Material number ($1 \leq m \leq 999$) $N_{k,m}$ = Atom density of Material m in Composition k ID_k = Composition identification (used in output only) </p> <p>2. Set 2</p> <p style="margin-left: 40px;"> k = Composition number ($1 \leq k \leq 100$) $\left(\frac{\phi_1}{\phi_2}\right)_k; \left(\frac{\phi_1}{\phi_3}\right)_k; \left(\frac{\phi_2}{\phi_3}\right)_k$ = Flux ratios for Composition k. If not supplied in the input, program sets them equal to 1. </p>																								
<p>D. Input Deck Makeup</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Card Number</th> <th style="text-align: left; border-bottom: 1px solid black;">Description</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Charge Card</td> </tr> <tr> <td>2</td> <td>Case Card</td> </tr> <tr> <td>3</td> <td>Type 1, Problem Option Card</td> </tr> <tr> <td>•</td> <td></td> </tr> <tr> <td>•</td> <td></td> </tr> <tr> <td>4</td> <td>Type 2, Composition Cards</td> </tr> <tr> <td>•</td> <td></td> </tr> <tr> <td>n</td> <td></td> </tr> <tr> <td>$n+1$</td> <td>99 card</td> </tr> <tr> <td>$n+2$</td> <td>Last Card</td> </tr> </tbody> </table>			Card Number	Description	1	Charge Card	2	Case Card	3	Type 1, Problem Option Card	•		•		4	Type 2, Composition Cards	•		n		$n+1$	99 card	$n+2$	Last Card
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AUTHORIZED BY <div style="text-align: right;">ABR</div>	REPLACES	DATE ISSUED <div style="text-align: right;">8-23-65</div>																						
WRITTEN BY <div style="text-align: right;">AJN</div>	REVISION NO.	CODE <div style="text-align: right;">HELM, IV-2</div>																						

SYSTEM SPECIFICATION

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COMPUTATION AND DATA PROCESSING

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CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION <div style="text-align: center;">HELM</div>	☐ → PRELIMINARY FINAL → ☒																																
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AUTHORIZED BY <div style="text-align: center;">ABR</div>	REPLACES	DATE ISSUED 8-23-65																																
WRITTEN BY <div style="text-align: center;">AJN</div>	REVISION NO.	CODE HELM, IV-3																																

SYSTEM SPECIFICATION

ATOMIC PRODUCTS DIVISION
COMPUTATION AND DATA PROCESSING

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION <div style="text-align: center;">HELM</div>	☐ PRELIMINARY ☒ FINAL
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	<u>Column</u>	<u>Word No.</u>	<u>Format</u>	<u>Content</u>
	1-3			ΔΔ 2
	4-6		I3	Composition number
	7-9		I3	Card Count starting at one for each composition
	14-80	1	fixed	Material number
		2	floating	Concentration
		3		Repeat Words 1 and 2 for each
		4		material in the composition.
		5		The card count must be increased
		6		for each new card used.
5. 99 Card				
	<u>Column</u>	<u>Content</u>		
	1-3	999		
6. Last Card				
	<u>Column</u>	<u>Content</u>		
	1-9	)LASTΔΔΔ*		

F. HELM FILE TAPE DESCRIPTION

Let f denote file name, F order of file f on HELM file tape, and N_F number of materials in file f , i. e., in the F^{th} file. Then the format of the HELM file tape is as follows:

<u>Blocks</u>	<u>Format</u>
1→2	Tape Dictionary
	Word 1 Tape identification (6 characters)
	Words 2-61 Control words for file-reading subroutine. Two consecutive words per file, with the second word of each pair containing the file name.
$3 \rightarrow (5 + 2N_1)$	Data for first file
$(6 + 2N_1) \rightarrow [8 + 2(N_1 + N_2)]$	Data for second file
$[9 + 2(N_1 + N_2)] \rightarrow [11 + 2(N_1 + N_2 + N_3)]$	Data for third file
(etc.)	
$\left[3 + 3F_{\max} + 2 \sum_{F=1}^{F_{\max}} N_F \right]$	Last block - 9999, 0, 0, 0

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SYSTEM SPECIFICATION

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CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION <div style="text-align: center;">HELM</div>	☐ → PRELIMINARY FINAL → ☒												
<p>The data for each file are as follows:</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; width: 20%;"><u>Block</u></th> <th style="text-align: left; width: 80%;"><u>Data for File</u></th> </tr> </thead> <tbody> <tr> <td style="vertical-align: top;">1st</td> <td> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> Word 1 Word 2 Word 3 Word 4 Word 5 Word 6, N + 5 </div> <div style="width: 70%;"> - f, file name (5 characters) - I, number of lethargy groups - J, number of inelastic groups - N, number of materials in file - MDS, maximum number of groups any material can downscatter - The material numbers* in the order they appear in the file </div> </div> </td> </tr> <tr> <td colspan="2" style="text-align: right; padding-right: 20px;"> *Material numbers 900-989 are reserved for (n, 2n) materials, 990-999 for hydrogen (SG) materials, and 1-899 for all others </td> </tr> <tr> <td style="vertical-align: top;">2nd</td> <td>$(\chi_i, i=1, I)$</td> </tr> <tr> <td style="vertical-align: top;">3rd</td> <td>$(\Delta u_i, i=1, I)$</td> </tr> <tr> <td style="vertical-align: top;">4th → (3 + 2 N_F)th</td> <td> <p>Two consecutive blocks for each material:</p> <p>1. $\left(\left[\left\{ \sigma_{in} \right\}_{i \rightarrow j, m}, j=i+1, K \right], i=1, J-1 \right)$</p> <p style="margin-left: 40px;">where K = MDS + i when i ≤ J - MDS K = J when i > J - MDS</p> <p>2. $\left(\left[\left[\sigma_{tr} \right]_{i, m}, \left[\sigma_f \right]_{i, m}, \left[\sigma_c \right]_{i, m}, \left[\sigma_{er} \right]_{i, m}, \left[\sigma_{in} \right]_{i, m} \text{ or } \left[\sigma_{sh} \right]_{i, m}, \right. \right.$ $\left. \left. \nu_{i, m}, i=1, I \right), m \right)$</p> </td> </tr> </tbody> </table>			<u>Block</u>	<u>Data for File</u>	1 st	<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> Word 1 Word 2 Word 3 Word 4 Word 5 Word 6, N + 5 </div> <div style="width: 70%;"> - f, file name (5 characters) - I, number of lethargy groups - J, number of inelastic groups - N, number of materials in file - MDS, maximum number of groups any material can downscatter - The material numbers* in the order they appear in the file </div> </div>	*Material numbers 900-989 are reserved for (n, 2n) materials, 990-999 for hydrogen (SG) materials, and 1-899 for all others		2 nd	$(\chi_i, i=1, I)$	3 rd	$(\Delta u_i, i=1, I)$	4 th → (3 + 2 N _F) th	<p>Two consecutive blocks for each material:</p> <p>1. $\left(\left[\left\{ \sigma_{in} \right\}_{i \rightarrow j, m}, j=i+1, K \right], i=1, J-1 \right)$</p> <p style="margin-left: 40px;">where K = MDS + i when i ≤ J - MDS K = J when i > J - MDS</p> <p>2. $\left(\left[\left[\sigma_{tr} \right]_{i, m}, \left[\sigma_f \right]_{i, m}, \left[\sigma_c \right]_{i, m}, \left[\sigma_{er} \right]_{i, m}, \left[\sigma_{in} \right]_{i, m} \text{ or } \left[\sigma_{sh} \right]_{i, m}, \right. \right.$ $\left. \left. \nu_{i, m}, i=1, I \right), m \right)$</p>
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AUTHORIZED BY <div style="text-align: center;">ABR</div>	REPLACES	DATE ISSUED 8-23-65												
WRITTEN BY <div style="text-align: center;">AJN</div>	REVISION NO.	CODE HELM, IV-5												

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CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION HELM	☐ → PRELIMINARY FINAL → ☒
<p>V. <u>DERIVATION OF EQUATIONS</u></p> <p>The calculations performed by HELM have been divided into three cases. The first case is completely independent, whereas cases 2 and 3 are dependent on the values calculated by Case 1 but they are independent of each other. The derivation of the equations used by each of the cases is given here.</p> <p>A. <u>Case 1</u></p> <p>This case calculates those macroscopic cross sections which have physical significance. The equations used are straightforward and require no detailed discussion. However, two comments should be made:</p> <ol style="list-style-type: none"> 1. The values calculated here are not directly applicable as PDQ input but they are supplied in the output primarily for the convenience of the user. 2. Hydrogen scattering has been treated by the Selengut Goertzel approximation. <p>B. <u>Case 2</u></p> <p>These equations are also straightforward and do not require a detailed explanation. The macroscopic values calculated here are simply those which are defined by the PDQ diffusion equations. Note, however, that the treatment of (n, 2n) reactions is not correct in that these equations conserve neutrons at the expense of eliminating the possibility of (n, 2n) reactions. The usual means of treating an (n, 2n) reaction is to have</p> $(\Sigma_{in})_{k,i} = \frac{1}{2} \sum_{j=i+1}^J (\Sigma_{in})_{k,i-j}$ <p>for certain Groups i. However, since PDQ sets the removal events from Group i equal to the source (from scattering only) events for Group i + 1, it is not possible to have different sources and removals for scattering events as required by the above equation. Thus for the calculations of Case 2 it is assumed that macroscopic inelastic cross section is always equal to the sum of the inelastic matrix. The total inelastic cross section in the file for each material is completely ignored.</p> <p>For essentially the same reasons as given above, the possibility of multigroup scattering is ignored.</p>		
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<p>C. <u>Case 3</u></p> <p>This option calculates macroscopic cross sections which attempt to compensate for multigroup scattering and the presence of (n, 2n) materials.</p> <p>Two methods are used, depending on the presence of a fission material in the composition for which the macroscopic cross sections are calculated. If a fission material is present, input flux ratios are used to redefine the macroscopic absorption and removal cross sections. <u>This method should always be used for PDQ input</u>; for nonfuel compositions, a fictitious fuel atom density, e. g., $N(\text{U-238}) = 10^{-10}$ atoms/barn·cm, should be added to the composition input. If no fission material is present, fictitious chi and macroscopic nu-fission cross sections are defined, along with a redefinition of the macroscopic absorption and removal cross sections. This feature was programmed into HELM with the expectation that composition-dependent chi values could be used in PDQ together with composition-dependent macroscopic nu-fission cross sections. However, this is not the case; although the PDQ program accepts composition-dependent chi values (for use in adjoint-flux calculations when macroscopic nu-fission cross sections are composition independent), the use of these in a flux calculation leads to error in the results.</p> <p>The equations-solved by PDQ are:⁽¹⁾</p> $\left\{ -\nabla \left[D_i(x) \nabla \phi_i(x) \right] + \left[\left(\Sigma_a(x) \right)_i + \left(\Sigma_r(x) \right)_i + D_i(x) B_Z^2 \right] \phi_i(x) \right. \\ \left. = \chi_i(x) \frac{\psi_i}{\lambda} + \left(\Sigma_r(x) \right)_{i-1} \phi_{i-1}(x) \right\}_{i=1}^I$ <p>where:</p> $\left(\Sigma_r(x) \right)_0 = 0, \text{ and}$ $\psi_i(x) = \sum_{i=1}^I \left(\nu \Sigma_f(x) \right)_i \phi_i(x).$		
AUTHORIZED BY ABR	REPLACES	DATE ISSUED 8-23-65
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<p>As stated previously, PDQ is a few-group code and the scattering removals from Group i-1 are always used as the scattering source for Group i.</p> <p>The equations used to calculate the macroscopic cross sections for Case 3 are divided into two sets. These are discussed separately below. All the equations referred to are in Section III. For simplicity the subscript "k" has been deleted in the discussion below.</p> <p>1. When $\sum_{i=1}^I (\Sigma_f)_{k,i} \neq 0$</p> <p>For all fuel compositions, the values of D_i, $(\nu\Sigma_f)_i$, $(\kappa\Sigma_f)_i$, and χ_i are defined the same as for Case 2. This assures that the fission neutron source in the fuel material does not contain fictitious sources. The multigroup scattering and (n, 2n) reactions are handled by redefining the $(\Sigma_a)_i$ and $(\Sigma_r)_i$ values. The method of doing this is basically simple. The value of $(\Sigma_r)_i$ was defined so that it would always give the correct source term in Group i+1 but not the correct removals from Group i. The correct number of removals from Group i is then obtained by adding or subtracting terms from $(\Sigma_a)_i$ as required. The complications arise when including 1 to 3 scattering [i.e., $(\Sigma_{SG})_{1-3}$ in $(\Sigma_r)_2$] since this value is multiplied by $\phi_2(x)$ in the diffusion equation whereas it should be multiplied by $\phi_1(x)$ to give the correct source for Group 3. Thus it becomes necessary to include the average factor of (ϕ_1/ϕ_2) in Equation 3.9. The (n, 2n) reaction is handled by always using the inelastic scattering matrix in calculating the "removal" cross sections, $(\Sigma_r)_i$, since these are used as source terms. The "absorption" cross section is then defined so that the sum of the "removal" and "absorption" cross sections contains only the term (Σ_{in}). For example, in adding Equations 3.6 and 3.7, the $(\Sigma_{in})_{1-2}$ terms cancel and only the term $(\Sigma_{in})_1$ remains which gives the correct removals from Group 1 for an (n, 2n) material. The same procedure is followed for all the groups.</p> <p>2. When $\sum_{i=1}^I (\Sigma_f)_{k,i} = 0$</p> <p>The derivation of the equations for non-fuel materials is quite different from that for fuel materials.</p>		
AUTHORIZED BY <div style="text-align: center;">ABR</div>	REPLACES	DATE ISSUED <div style="text-align: center;">8-23-65</div>
WRITTEN BY <div style="text-align: center;">AJN</div>	REVISION NO.	CODE <div style="text-align: center;">HELM, V-3</div>

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CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION HELM	☐ PRELIMINARY ☒ FINAL
<p>The procedure used to develop the necessary equations is as follows. All scatterings over a group (i. e., Groups 1 to 3, 1 to 4, and 2 to 4) are treated as fission processes and the chi values are so defined that the correct fraction of scatterings are placed in Groups 3 and 4. The chi values for Groups 1 and 2 are set equal to zero so that no "fission" neutrons appear in these groups. The correct source in Group i is then obtained by defining the value of $(\Sigma_r)_{i-1}$ so that the sum of the terms $\chi_i \psi_i \phi_i$ and $(\Sigma_r)_{i-1} \phi_{i-1}$ gives the correct source in Group i. The correct number of removals from Group i is then obtained by defining $(\Sigma_a)_i$ such that the sum of $(\Sigma_a)_i + (\Sigma_r)_i$ gives the correct value for removals from Group i. The presence of (n, 2n) materials is accounted for by exactly the same procedure as that described for fuel materials. Note that this procedure is exact in that it does not require a previous knowledge of the flux ratios. The same method as that used for the fuel materials could have been used here if so desired.</p> <p>The easiest way to assure that the equations of Section III are correct is to substitute the values of $(\Sigma_a)_i$, $(\Sigma_r)_i$, χ_i, and $(\nu \Sigma_f)_i$ into the diffusion equation and see if they give the correct removal and source terms. When this is done, several features become apparent. Although HELM has essentially been written for four groups, the equations are found to be also valid for 1, 2, or 3 groups if the non-existent cross sections [i. e., $(\Sigma_{SG})_{1-4}$ for $I = 3$] are assumed to be equal to zero. The only inexact terms for a fuel material are the scattering source terms for Groups 3 and 4. This is due to the assumption of a previous knowledge of the flux ratios. All other source and removal terms which contain values multiplied by a flux ratio are found to have two terms which exactly cancel.</p>		
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WRITTEN BY AJN	REVISION NO.	CODE HELM, V-4

**ATOMIC PRODUCTS DIVISION
COMPUTATION AND DATA PROCESSING**

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION	☐ PRELIMINARY FINAL ☒
HELM		
VI. SAMPLE INPUT		
The following is the card listing of the input deck for the sample HELM problem.		
<pre>CHARGE 093 AJN A JOSEPH NARDI EXT 2014 BLDG A ROOM 140D)HELMAJN*PDQ15 093 09AUG65 1 1 SH04C4E 1.0 1 1 1 2 1000 5H CORE 0.2974378 3.57701 12.02607 2 1001 004 .63982-2 008 .24667-1 011 .54343-2 026 .19324-1 2 1002 284 .77644-2 494 .13698-2 2 2000 6HREFLEC 2 2001 028 .52550-1 2 3000 6H R4C 2 3001 005 .78459-1 006 .19615-1 2 4000 6H SERP 2 4001 008 .54796-1 214 .91327-2 999 .18266-1 99)LAST *</pre>		
0022 CARDS 09-03-65 PAGE 001 OF 001		
AUTHORIZED BY	REPLACES	DATE ISSUED
ABR		8-23-65
WRITTEN BY	REVISION NO.	CODE
AJN		HELM, VI-1

SYSTEM SPECIFICATION

ATOMIC PRODUCTS DIVISION
COMPUTATION AND DATA PROCESSING

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION <div style="text-align: center; font-weight: bold;">HELM</div>	☐ → PRELIMINARY ☒ → FINAL
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VII. SAMPLE OUTPUT

Included here is a listing of both the printed output and the punched cards supplied by HELM for the sample problem given in Section VI.

HFLM-X CHG # 093 AJN CASE # PDQ15 09AUG65 TIME 081265 1620.2 PAGE 1

CASE 1 CROSS SECTION EDIT

COMPOSITION 1 CORE
CONTAINS MATERIALS:

	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
	4	0.63982-002	8	0.24667-001	11	0.54343-002	26	0.19324-001
	284	0.77644-002	494	0.13698-002				

GROUP	DIFFUSION	CAPTURE	FISSION	AVG NU	ELASTIC REMOVAL	INELASTIC	HY REMOVAL
1	0.20055+001	0.10833-002	0.40055-002	0.29726+001	0.13787-001	0.10122-001	0.
2	0.98677+000	0.33906-002	0.26152-002	0.29118+001	0.37670+003	0.15464-002	0.
3	0.72549+000	0.16124-001	0.95133-002	0.29000+001	0.21737+006	0.	0.
4	0.14010+000	0.74173+000	0.11725+001	0.29000+001	0.	0.	0.

INELASTIC MATRIX

I	J	1	2	3	4
1	0.	0.1256-001	0.	0.	0.
2	0.	0.	0.1546-002	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

HYDROGEN MATRIX

I	J	1	2	3	4
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

COMPOSITION 2 REFLEC
CONTAINS MATERIALS:

	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
	28	0.52550-001						

GROUP	DIFFUSION	CAPTURE	FISSION	AVG NU	ELASTIC REMOVAL	INELASTIC	HY REMOVAL
1	0.24397+001	0.32016+003	0.	0.	0.41787+002	0.26028-002	0.
2	0.65712+000	0.78825-003	0.	0.	0.19334+002	0.	0.
3	0.41703+000	0.29366-002	0.	0.	0.60394+006	0.	0.
4	0.32856+000	0.13138+000	0.	0.	0.	0.	0.

INELASTIC MATRIX

I	J	1	2	3	4
1	0.	0.2683-002	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

HYDROGEN MATRIX

I	J	1	2	3	4
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

AUTHORIZED BY <div style="text-align: center;">ABR</div>	REPLACES	DATE ISSUED <div style="text-align: center;">8-23-65</div>
WRITTEN BY <div style="text-align: center;">AJN</div>	REVISION NO.	CODE <div style="text-align: center;">HELM, VII-1</div>

CASE 1 CROSS SECTION EDIT

COMPOSITION 3 B4C
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
5	0.78459-001	6	0.19615-001				

GROUP	DIFFUSION	CAPTURE	FISSION	AVG NU	ELASTIC REMOVAL	INELASTIC	HY REMOVAL
1	0.19056+001	0.40953-002	0.	0.	0.26567+001	0.	0.
2	0.83749+000	0.43133-001	0.	0.	0.41884+002	0.74276-003	0.
3	0.44593+000	0.35167+000	0.	0.	0.47805+004	0.	0.
4	0.21784-001	0.14902+002	0.	0.	0.	0.	0.

INELASTIC MATRIX

I	J	1	2	3	4
1	0.	0.	0.	0.	0.
2	0.	0.	0.7428-003	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

HYDROGEN MATRIX

I	J	1	2	3	4
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

COMPOSITION 4 SERP
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
8	0.54796-001	214	0.91327-002	999	0.18266-001		

GROUP	DIFFUSION	CAPTURE	FISSION	AVG NU	ELASTIC REMOVAL	INELASTIC	HY REMOVAL
1	0.18844+001	0.17070-003	0.	0.	0.17633+001	0.20384-003	0.19828-001
2	0.10129+001	0.74535-005	0.	0.	0.12304+003	0.99048-003	0.47587-001
3	0.97399+000	0.36410-003	0.	0.	0.15996+003	0.	0.45088-001
4	0.48599+000	0.59945-002	0.	0.	0.	0.	0.

INELASTIC MATRIX

I	J	1	2	3	4
1	0.	0.2038-003	0.	0.	0.
2	0.	0.	0.9905-003	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.

HYDROGEN MATRIX

I	J	1	2	3	4
1	0.	0.1975-001	0.8101-004	0.2460+007	
2	0.	0.	0.4757-001	0.1444-004	
3	0.	0.	0.	0.4509+001	
4	0.	0.	0.	0.	

LM-X CHG # 093 AJN CASE # PDO 09AUG65 TIME 081265 1620.2 PA 3

CASE 2 CROSS SECTION EDIT

COMPOSITION 1 CORE
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
4	0.63982-002	8	0.24667-001	11	0.54343-002	26	0.19324-001
284	0.77644-002	494	0.13698-002				

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.20055+001	0.50888-002	0.26349-001	0.11907-001	0.40055-002	0.87200+000
2	0.98677+000	0.60057-002	0.19231-002	0.76147-002	0.26152-002	0.12800+000
3	0.72549+000	0.25637-001	0.21737-006	0.27589-001	0.95133-002	0.
4	0.14010+000	0.19143+001	0.	0.34004+001	0.11725-001	0.

COMPOSITION 2 REFLEC
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
28	0.52550-001						

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.24397+001	0.32016-003	0.68616-002	0.	0.	0.87200+000
2	0.65712+000	0.78825-003	0.19334-002	0.	0.	0.12800+000
3	0.41703+000	0.29366-002	0.60394-006	0.	0.	0.
4	0.32856+000	0.13138+000	0.	0.	0.	0.

VII-3

GEAP-4953

PLM-X CHG # 093 AJN CASE # PD015 09AUG65 TIME 081265 1620.2 PAGE 4
CASE 2 CROSS SECTION EDIT

COMPOSITION 3 B4C
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
5	0.78459-001	6	0.19615-001				

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.19056+001	0.40953-002	0.26567-001	0.	0.	0.87200+000
2	0.83749+000	0.43133-001	0.49312-002	0.	0.	0.12800+000
3	0.44593+000	0.35167+000	0.47805-004	0.	0.	0.
4	0.21784+001	0.14902+002	0.	0.	0.	0.

COMPOSITION 4 SERP
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
8	0.54796-001	214	0.91327-002	999	0.18266-001		

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.18844+001	0.17070-003	0.37665-001	0.	0.	0.87200+000
2	0.10129+001	0.74535-005	0.48700-001	0.	0.	0.12800+000
3	0.97399+000	0.36410-003	0.45248-001	0.	0.	0.
4	0.48599+000	0.59945-002	0.	0.	0.	0.

VII-4

GEAP-4953

ELM-X CHG # 093 AJN CASE # PD 5 09AUG65 TIME 081265 1620.2 PAGE 5

CASE 3 CROSS SECTION EDIT

COMPOSITION 1 CORE

CONTAINS MATERIALS:		MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
		4	0.63982-002	8	0.24667-001	11	0.54343-002	26	0.19324-001
		284	0.77644-002	494	0.13698-002				

FLUX RATIOS: GROUP 1/2 = 0.29744+000 GROUP 1/3 = 0.35770+001 GROUP 2/3 = 0.12026+002

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.20055+001	0.26490-002	0.26349-001	0.11907+001	0.40055-002	0.87200+000
2	0.98677+000	0.60057-002	0.19231-002	0.76147-002	0.26152-002	0.12800+000
3	0.72549+000	0.25637-001	0.21737-006	0.27589-001	0.95133-002	0.
4	0.14010+000	0.19143+001	0.	0.34004+001	0.11725+001	0.

COMPOSITION 2 REFLEC

CONTAINS MATERIALS:		MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
		28	0.52550-001						

FLUX RATIOS: GROUP 1/2 = 0.10000+001 GROUP 1/3 = 0.10000+001 GROUP 2/3 = 0.10000+001

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.24397+001	0.32016-003	0.68616-002	0.	0.	0.
2	0.65712+000	0.78825-003	0.19334-002	0.	0.	0.
3	0.41703+000	0.29366-002	0.60394-006	0.	0.	0.
4	0.32856+000	0.13138+000	0.	0.	0.	0.

VII-5

GEAP-4953

M-X CHG # 093 AJN CASE # PDQ 09AUG65 TIME 081265 1620.2 PA 6

CASE 3 CROSS SECTION EDIT

COMPOSITION 3 B4C
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
5	0.78455-001	6	0.19615-001				

FLUX RATIOS: GROUP 1/2 = 0.10000+001 GROUP 1/3 = 0.10000+001 GROUP 2/3 = 0.10000+001

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.19056+001	0.40953-002	0.26567-001	0.	0.	0.
2	0.83749+000	0.43133-001	0.49312-002	0.	0.	0.
3	0.44593+000	0.35167+000	0.47805-004	0.	0.	0.
4	0.21784-001	0.14902+002	0.	0.	0.	0.

COMPOSITION 4 SERP
CONTAINS MATERIALS:

MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.	MAT NO	CONC.
8	0.54795-001	214	0.91327-002	999	0.18266-001		

FLUX RATIOS: GROUP 1/2 = 0.10000+001 GROUP 1/3 = 0.10000+001 GROUP 2/3 = 0.10000+001

GROUP	DIFFUSION	ABSORPTION	REMOVAL	NU FISSION	KAPPA FISSION	CHI
1	0.18844+001	0.25173-003	0.37584-001	0.81033-004	0.	0.
2	0.10129+001	0.47594-001	0.11135-002	0.47587-001	0.	0.
3	0.97399+000	0.36410-003	0.45248-001	0.	0.	0.99970+000
4	0.48599+000	0.59945-002	0.	0.	0.	0.30354-003

VII-6

GEAP-4953

SYSTEM SPECIFICATION

ATOMIC PRODUCTS DIVISION
COMPUTATION AND DATA PROCESSING

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)

DESCRIPTION

HELM

☐ PRELIMINARY

☒ FINAL

B. Listing of Punched Cards

CASE 2
Output

CASE 3
Output

```

2 CORE 021001.2005472+0.5088819-02.2634852-01.1190665-01.4005526-02. 1
2 REFLEC 021002.2439679+0.3201609-03.8861558-02.0000000+00.0000000+00. 2
2 B4C 021003.1905618+01.4095281-02.2656713-01.0000000+00.0000000+00. 3
2 SERP 021004.1884392+01.1706990-03.3766497-01.0000000+00.0000000+00. 4
2 CORE 022001.9867674+00.6005711-02.1923082-02.7614709-02.2615156-02. 1
2 REFLEC 022002.6571185+00.7882500-03.1933420-02.0000000+00.0000000+00. 2
2 B4C 022003.8374886+00.4313328-01.4931188-02.0000000+00.0000000+00. 3
2 SERP 022004.1012906+01.7453499-05.4870050-01.0000000+00.0000000+00. 4
2 CORE 023001.7254872+00.2563707-01.2173663-06.2758861-01.9513315-02. 1
2 REFLEC 023002.4170345+00.2936586-02.6039437-06.0000000+00.0000000+00. 2
2 B4C 023003.4459331+00.3516700+00.4780526-04.0000000+00.0000000+00. 3
2 SERP 023004.9739851+00.3641043-03.4524750-01.0000000+00.0000000+00. 4
2 CORE 024001.1401047+00.1914280+01.0000000+00.3400392+01.1172549+01. 1
2 REFLEC 024002.3285593+00.1313750+00.0000000+00.0000000+00.0000000+00. 2
2 B4C 024003.2178384-01.1490177+02.0000000+00.0000000+00.0000000+00. 3
2 SERP 024004.4859937+00.5994493-02.0000000+00.0000000+00.0000000+00. 4
031001.8720000+00. 4
032001.1280000+00. 4
033001.0000000+00. 4
034001.0000000+00. 4
3 CORE 021001.2005472+01.2649026-02.2634852-01.1190665-01.4005526-02. 1
3 REFLEC 021002.2439679+01.3201619-03.6861558-02.0000000+00.0000000+00. 2
3 B4C 021003.1905618+01.4095281-02.2656713-01.0000000+00.0000000+00. 3
3 SERP 021004.1884392+01.2517322-03.3758394-01.8103319-04.0800000+00. 4
3 CORE 022001.9867674+00.6005712-02.1923082-02.7614709-02.2615156-02. 1
3 REFLEC 022002.6571185+00.7882500-03.1933420-02.0000000+00.0000000+00. 2
3 B4C 022003.8374886+C0.4313328-01.4931188-02.0000000+00.0000000+00. 3
3 SERP 022004.1012906+C1.4759443-01.1113522-02.4758698-01.0000000+00. 4
3 CORE 023001.7254872+C0.2563707-01.2173663-06.2758861-01.9513315-02. 1
3 REFLEC 023002.4170345+00.2936586-02.6039437-06.0000000+00.0000000+00. 2
3 B4C 023003.4459331+00.3516700+00.4780526-04.0000000+00.0000000+00. 3
3 SERP 023004.9739851+00.3641043-03.4524750-01.0000000+00.0000000+00. 4
3 CORE 024001.1401047+00.1914280+01.0000000+00.3400392+01.1172549+01. 1
3 REFLEC 024002.3285593+00.1313750+00.0000000+00.0000000+00.0000000+00. 2
3 B4C 024003.2178384-01.1490177+02.0000000+00.0000000+00.0000000+00. 3
3 SERP 024004.4859937+00.5994493-02.0000000+00.0000000+00.0000000+00. 4
031001.8720000+00. 1.0000000+00. 2.0000000+00. 3.0000000+00. 4
032001.1280000+00. 1.0000000+00. 2.0000000+00. 3.0000000+00. 4
033001.0000000+00. 1.0000000+00. 2.0000000+00. 3.9996965+00. 4
034001.0000000+00. 1.0000000+00. 2.0000000+00. 3.3035391-02. 4

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0040 CARDS 08-23-65 PAGE 001 OF 001

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WRITTEN BY

AJN

REVISION NO.

CODE

HELM, VII-7

DATE ISSUED

8-23-65

SYSTEM SPECIFICATION

ATOMIC PRODUCTS DIVISION
COMPUTATION AND DATA PROCESSING

GEAP-4953

CUSTOMER APPROVAL (NAME & DATE)	DESCRIPTION HELM	☐ PRELIMINARY FINAL ☒
<p>VIII. <u>REFERENCES</u></p> <ol style="list-style-type: none">1. Bilodeau, G. G., Cadwell, W. R., Dorsey, J. P., Fairey, J. G., and Varga, R. S., "PDQ, An IBM-704 Code to Solve the Two-Dimensional Few-Group Neutron Diffusion Equations," WAPD-TM-70 (August 1957).2. Cadwell, W. R., "PDQ-3, A Program for the Solution of the Neutron-Diffusion Equations in Two Dimensions on the IBM-704," WAPD-TM-179 (May 1960).		
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