NAVY DEPARTMENT

THE DAVID W. TAYLOR MODEL BASIN

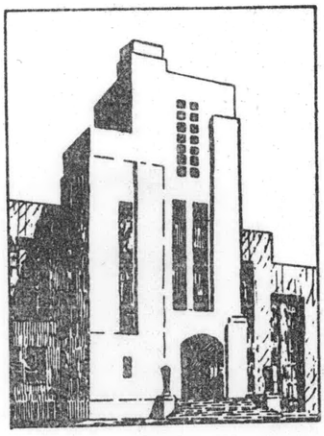
WASHINGTON 7, D.C.

RDR 4 INSTRUCTION MANUAL

DAVID TAYLOR MODEL BASIN ONE-DIMENSIONAL, ONE-GROUP TRANSPORT THEORY ROUTINE NO. 4 FOR NUCLEAR REACTOR DESIGN

by

Charles W. Dawson and Erwin H. Bareiss



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Miss Pauline Smiley, while detailed to the David Taylor Model Basin as a student programmer from the Westinghouse Atomic Power Division, coded the greater part of the NORC Routine described herein. Miss Mary Lou Crane programmed the directional flux output for the UNIVAC

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DAVID TAYLOR MODEL BASIN
APPLIED MATHEMATICS LABORATORY

NORC - TRANSPORT THEORY ROUTINE NO. 4 FOR NUCLEAR REACTOR DESIGN

(RDR 4)

This code furnishes an approximate transport theory solution to problems with the following characteristics:

One dimensional, slab geometry, single energy, with anisotropic scattering and isotropic sources

(a) with two reflecting boundaries:

$$F(\theta) = F(\pi - \theta)$$

(b) with two free boundaries: F incident = 0

(c) with one free and one reflecting boundary.

Other boundary conditions may be handled on special request, including point source at boundary.

A maximum of ninety regions (each different), can be handled by the code.

The maximum number of lattice points, N, is determined by the following expression:

$$N = \frac{12}{L} (509 - R)$$

where R is the number of regions, and L is the number of angles at which the vector fluxes are calculated. L may be 8, 10 or 12. Unless otherwise requested, Double-Gauss quadrature formulas will be applied for the angular integration. The methods of integration are described in:

Bareiss, E.H., "Flexible Transport Theory Routines for Nuclear Reactor Design", DTMB Report 1030 (1956)

_____, "Nuclear Reactor Calculations At DTMB", AML Technical Report 15, February 1956

Input Data

The input data must contain the following quantities for each region:

$$n; \quad x\cdot\Sigma^T; \quad \Sigma^S/\Sigma^T; \quad S/\Sigma^T; \quad a_1; \quad a_2; \quad F_1; \quad F_r,$$

where n = number of lattice points in the region, including both end points.

Δx = distance between lattice points in the region in cm.

Σ^T = total cross section in the region, in cm^{-1}.

Σ^S = scattering (non removal) cross section in the region in cm^{-1}. Σ^S/Σ^T must be non zero but may be as small as (10^{-7}).

S = total source in the region, in $cm^{-3}\cdot sec^{-1}$.

The coefficients a_1 and a_2 are defined as follows:

$$\Sigma^S(\mu^*) = \frac{1}{2}\Sigma^S\left[P_o(\mu^*) + a_1P_1(\mu^*) + a_2P_2(\mu^*) + \cdots\right]$$

where $\mu^* = \cos(\theta - \theta')$, i.e. cosine of the scattering angle $(\theta - \theta')$

$P_i(\mu)$ = Legendre polynomials

$$\Sigma^S = \int_{-1}^{+1}\Sigma^S(\mu)d\mu$$

F_1 and F_r are the estimated average vector fluxes at the left and right boundaries of the region. If no better information is available use:

$$F_1 = F_r = \frac{1}{2}\frac{S/\Sigma^T}{(1 - \Sigma^S/\Sigma^T)}$$

The input should be supplied on forms similar to the attached sample. The first card is the Beginning Of Block (BOB) card. Word I is the BOB word and contains the block number. Word II contains the problem identification number. Word III is filled with zeros, which may be indicated by the mark $\sim$. Word IV is all zeros except for the last two digits which contain the number of specified angles (L).

The next card represents the first region. Fill in the quantities as indicated by the column headings. The quantities must be given in the form shown below:

n	00000nnn.	a_1	$\pm$.xxxxxxx
$\Delta x \Sigma^T$	.xxxxxxxx	a_2	$\pm$.xxxxxxx
Σ^S/Σ^T	x.xxxxxxx	F_1	ee+x.xxxx
S/Σ^T	x.xxxxxxx	F_r	ee+x.xxxx

where (+) is represented by a (0) and (-) by a (1). ee is an exponent; 01, 02, 03, 04 stand for 10^1, 10^2, 10^3, 10^4, respectively; 99 stands for 10^{-1}, 98 for 10^{-2},... 95 for 10^{-5}. Because other parts of the code use a one digit exponent, the exponent should be less than or equal to 04 and greater than or equal to 95 (-5).

After the last region, insert the End of Block (EOB) card. Word I of the EOB card is all nines. Word II is the EOB word and contains the block number. Words III and IV should be left blank.

After the last problem, add an End of File block (EOF block) with one word of zeros.

The first region on the sample data sheet has the following values

n = 102	a_1 = + .32
$\Delta x \cdot \Sigma^T$ = .1	a_2 = - .00012
Σ^S/Σ^T = 0.453	F_1 = 0.46
S/Σ^T = 0.5	F_r = 1.89

Experience with Problems

Experience with problems run on RDR 4 indicate:

(a) Five significant digits can be obtained with $\Delta x \cdot \Sigma^T = 0.025$ and L = 10 or 12

(b) Four significant digits can be obtained with $\Delta x \cdot \Sigma^T = 0.1$ and L = 8, 10, or 12.

(c) Three significant digits can be obtained with $\Delta x \cdot \Sigma^T = 0.2$ L = 8, 10, or 12.

(d) One should never use $\Delta x \cdot \Sigma^T > 0.4$

Out Put

a) At each lattice point the output contains the value of the transformed (dimensionless) space coordinate

$$x = \int_0^{\bar{x}} \Sigma^T(\bar{x}) d\bar{x}$$

$$\Sigma^S/\Sigma^T; \quad S/\Sigma^T; \quad a_1; \quad a_2;$$

and the scalar flux.

b) The average scalar flux for each region will appear beside the last point of that region.

c) The vector fluxes for the L angular directions can also be obtained. This will cause a delay in getting the results printed.

Address questions to Dr. Erwin H. Bareiss or Charles W. Dawson.

Originator:

Boundary	Reflecting	Free
Left		
Right		

Vector Fluxes	
Yes	
No	

Special Instructions:

		Word I		Word II		Word III		Word IV	
Block No.	Card No.	n	$\Delta x \cdot \Sigma^T$	Σ^S/Σ^T	S/Σ^T	a_1	a_2	F_1	F_r
		00000nnn.	.xxxxxxxx	x.xxxxxxx	x.xxxxxxx	±.xxxxxxx	±.xxxxxxx	ee+x.xxxx	ee+x.xxxx
									No. of Fluxes
				Problem Identification					
1	1	~BOB~	00000001	MMDD1956	00001234	~	~	~	00000008
	2	00000102	.10000000	0.4530000	0.5000000	0.3200000	1.0001200	9904.6000	0001.8900
	3	00000035	.10000000	0.9500000	1.0000000	1.2100000	~	0001.8900	0102.8000
	4	99999999	99999999	~EOB~	00000001				
2	1	~BOB~	00000002	~	00001235	~	~	~	00000010
	⋮								
	⋮								
	⋮								
		99999999	99999999	~EOB~	00000002				
EOF		~	~						

NORC - OPERATING INSTRUCTIONS FOR RDR 4

This part contains the necessary instructions for the operator at the NORC CONTROL CONSOLE. The problem originator does not have to be cognizant of its contents.

NORC Setup: The tapes are set up as follows:

Tape Function	Tape Code
Instruction tape	09 and 04
Input tape	02
Memory dump tape (Blank tape)	03
Output tape (Blank tape)	05

Set switches 64 and 65 on stop; 66, 67, and 68 on proceed; 74, 77, and 78 on off. The positions of the switches 75, 76, and 79 are determined by the boundary conditions and output desired as shown below.

Boundary	Reflecting	Free
Left	75 on off	75 on transfer
Right	76 on off	76 on transfer

Vector fluxes	Yes: 79 on transfer	No: 79 on off

Set memory switch for 3600 words.

Starting: The routine has a standard start.

Restarting: The restart procedure may be used any time after the routine has run for 10 seconds from the standard start. To restart, key

0994	0002	0007	0020	into 0001,

transfer to 0001, and push the start button. The output tape must be positioned by hand if its position was changed after stopping. The input tape will be positioned by the routine. It is not necessary to rewind the instruction tape, the input tape, or the memory dump tape when restarting.

Stopping: The routine will make a standard stop after finishing all the problems on the input tape. If it is necessary to stop before all the problems on the input tape are finished, set option switch 74 on off and the routine will come to a standard stop after having written the next memory dump.

Stops: If the NORC stops on a 61 order, just push the start button. If the stop is repeated several times consult the table of 61 stops below.

Table of 61 Stops

Line	Cause	
8	The memory switch is set for 2000 words	Set memory switch for 3600 words.
7 21 97 100 212 381 393 427	TCF while reading in instruction "	Replace instruction tape and do restarting procedure.
76	TCF while reading in input	Read forward one block on tape code 02 and transfer control to line 0008. (Therefore, this problem is omitted)
101 197 216	TCF while writing output " " " " " " " "	Try a different output tape on a different tape mechanism.
122 527	TCF while writing a memory dump " " " " " "	Try different blank tape on a different tape mechanism.
25	TCF while reading in memory dump	Rewind the instruction tape. Obtain the block number of the last problem completed from the last special function print out. Position the input tape (02) and the output tape (05) to the end of the blocks for the last problem completed and make a standard start.

Special Function Print Out: Upon completing a problem, the routine will make a special function print out. The last four digits of the first word will contain the number of the input block of the problem just completed.

If switch 79 is set on off there is one block of output per problem. This output block has the same block number as the input block.

If switch 79 is set on transfer there may be several blocks of output. A short sentinal block follows the output and has the same block number as the input block.

Out Put: Have cards made from tape code (05). If the output does not contain the vector fluxes (switch 79 on off), insert the heading cards 1, 2, and 3 after the Beginning of Block (BOB) card and list on board number 12. If the output does contain the vector fluxes (switch 79 on transfer), make a straight listing on board number 9 and mail the cards with the listing to

Charles Dawson
Code 842
David Taylor Model Basin
Washington 7, D. C.

for further processing.

UNIVAC INSTRUCTIONS FOR DIRECTIONAL FLUX OUTPUT

Preparation of Data Tape on Card to Tape Converter:

Remove the Beginning of Block (BOB) and End of Block (EOB) cards from each block. One problem may contain several blocks. The first card is all zeros and must be removed. The next card contains the identification word and the number of flux directions.

On card-to-tape-converter use plugboard 85 with zero fill. Complete the last block with sentinels (-) and add two more blocks of sentinels.

Tape Setup:

Instruction tape - Servo 1
Data Tape - Servo 5
Blank Tapes - Servos 4, 6, 8

The final output will be on tape 4.

Procedure:

Initial read S1, set blockettes on 4.
A stop at line 010 calls for type-ins to 374, 375.

Type in: date of UNIVAC operation
374 - ▲▲▲ΔΔΔ MON. ΔD
375 - YΔ YEAR ΔΔΔ ΔΔΔ

No breakpoints necessary.

Type-outs:

005	4-920	EDIT	Routine identification.
026	END	SORT	After directional fluxes have been separated from other data.
137	BEGIN	FLUX	Start of routine which edits fluxes.
559	END	EDIT	End of routine output on T-4.

Printing on High Speed Printer:

Use a 1-1 board with space between blocks.
Fast feed 1 in line 3
Fast feed 2 in line 9

Directional fluxes will be on the even numbered pages.