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======================================================================= Virgin
                                                                        Virgin
     PROGRAM VIRGIN                                                     Virgin
     VERSION 76-1 (NOVEMBER 1976)                                       Virgin
     VERSION 84-1 (JUNE 1984)   *DOUBLE PRECISION ENERGY                Virgin
     VERSION 86-1 (JANUARY 1986)*FORTRAN-77/H VERSION                   Virgin
     VERSION 88-1 (JULY 1988)   *OPTION...INTERNALLY DEFINE ALL I/O     Virgin
                                 FILE NAMES (SEE, SUBROUTINE FILEIO     Virgin
                                 FOR DETAILS).                          Virgin
                                *IMPROVED BASED ON USER COMMENTS.       Virgin
     VERSION 89-1 (JANUARY 1989)*PSYCHOANALYZED BY PROGRAM FREUD TO     Virgin
                                 INSURE PROGRAM WILL NOT DO ANYTHING    Virgin
                                 CRAZY.                                 Virgin
                                *UPDATED TO USE NEW PROGRAM CONVERT     Virgin
                                 KEYWORDS.                              Virgin
                                *ADDED LIVERMORE CIVIC COMPILER         Virgin
                                 CONVENTIONS.                           Virgin
     VERSION 92-1 (JANUARY 1992)*COMPLETE RE-WRITE                      Virgin
                                *OUTPUT IN PLOTTAB FORMAT               Virgin
                                *UP TO 2000 THICKNESSES                 Virgin
                                *INCREASED INCORE PAGE SIZE TO 6000     Virgin
                                 CROSS SECTION POINTS                   Virgin
                                *ADDED PHOTON CALCULATIONS              Virgin
                                *ADDED BLACKBODY SPECTRUM               Virgin
                                *ADDED MULTIPLE LAYERS                  Virgin
                                *ADDED SPATIALLY DEPENDENT DENSITY      Virgin
                                *ADDED FORTRAN SAVE OPTION              Virgin
                                *COMPLETELY CONSISTENT I/O ROUTINES -   Virgin
                                 TO MINIMIZE COMPUTER DEPENDENCE.       Virgin
     VERSION 92-2 (MAY 1992)    *CORRECTED TO HANDLE MULTIGROUP CROSS   Virgin
                                 SECTIONS AS INPUT IN ENDF/B FORMAT.    Virgin
     VERSION 96-1 (JANUARY 1996) *COMPLETE RE-WRITE                     Virgin
                                 *IMPROVED COMPUTER INDEPENDENCE        Virgin
                                 *ALL DOUBLE PRECISION                  Virgin
                                 *ON SCREEN OUTPUT                      Virgin
                                 *UNIFORM TREATMENT OF ENDF/B I/O       Virgin
                                 *IMPROVED OUTPUT PRECISION             Virgin
                                 *DEFINED SCRATCH FILE NAMES            Virgin
     VERSION 99-1 (MARCH 1999)   *CORRECTED CHARACTER TO FLOATING       Virgin
                                  POINT READ FOR MORE DIGITS            Virgin
                                 *UPDATED TEST FOR ENDF/B FORMAT        Virgin
                                  VERSION BASED ON RECENT FORMAT CHANGE Virgin
                                 *GENERAL IMPROVEMENTS BASED ON         Virgin
                                  USER FEEDBACK                         Virgin
     VERS. 2000-1 (FEBRUARY 2000)*GENERAL IMPROVEMENTS BASED ON         Virgin
                                  USER FEEDBACK                         Virgin
     VERS. 2002-1 (MAY 2002)     *OPTIONAL INPUT PARAMETERS             Virgin
     VERS. 2004-1 (MARCH 2004)   *ADDED INCLUDE FOR COMMON              Virgin
                                 *UP TO 2000 THICKNESSES                Virgin
                                 *INCREASED INCORE PAGE SIZE TO 60,000  Virgin
     VERS. 2007-1 (JAN.  2007)   *CHECKED AGAINST ALL ENDF/B-VII.       Virgin
                                 *INCREASED INCORE PAGE SIZE TO         Virgin
                                  240,000 FROM 60,000.                  Virgin
     VERS. 2007-2 (DEC.  2007)   *72 CHARACTER FILE NAME.               Virgin
     VERS. 2010-1 (Apr.  2010)   *General update based on user feedback Virgin
                                 *INCREASED INCORE PAGE SIZE TO         Virgin
                                  600,000 FROM 240,000.                 Virgin
     VERS. 2012-1 (Aug.  2012)   *Added CODENAME                        Virgin
                                 *32 and 64 bit Compatible              Virgin
                                 *Added ERROR stop                      Virgin
     VERS. 2015-1 (Jan.  2015)   *Extended OUT9.                       Virgin
                                 *Replaced ALL 3 way IF Statements.     Virgin
                                 *Generalized TART Group Structures.    Virgin
                                 *Generalized SAND-II Group Structures. Virgin
                                 *Extended SAND-II to 60, 150, 200 MeV. Virgin
                                                                        Virgin
     OWNED, MAINTAINED AND DISTRIBUTED BY                               Virgin
     ------------------------------------                               Virgin
     THE NUCLEAR DATA SECTION                                           Virgin
     INTERNATIONAL ATOMIC ENERGY AGENCY                                 Virgin
     P.O. BOX 100                                                       Virgin
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A-1400, VIENNA, AUSTRIA Virgin
EUROPE Virgin
Virgin
ORIGINALLY WRITTEN BY Virgin
---------- Virgin
Dermott E. Cullen Virgin
Virgin
PRESENT CONTACT INFORMATION Virgin
---------- Virgin
Dermott E. Cullen Virgin
1466 Hudson Way Virgin
Livermore, CA 94550 Virgin
U.S.A. Virgin
Telephone 925-443-1911 Virgin
E. Mail RedCullen1@Comcast.net Virgin
Website http://home.comcast.net/~redcullen1 Virgin
Virgin
PURPOSE Virgin
------- Virgin
THIS PROGRAM IS DESIGNED TO CALCULATE UNCOLLIDED (I.E. VIRGIN) Virgin
FLUX AND REACTIONS DUE TO TRANSMISSION OF A MONODIRECTIONAL Virgin
BEAM OF NEUTRONS THROUGH ANY THICKNESS OF MATERIAL. IN ORDER Virgin
TO SIMULATE AN EXPERIMENTAL MEASUREMENT THE RESULTS ARE GIVEN Virgin
AS INTEGRALS OVER ENERGY TALLY GROUPS (AS OPPOSED TO POINTWISE Virgin
IN ENERGY). BY TAKING THE RATIO OF REACTIONS TO FLUX IN EACH Virgin
GROUP AN EQUIVALENT SPATIALLY DEPENDENT GROUP AVERAGED CROSS Virgin
SECTION IS CALCULATED BY THE PROGRAM. Virgin
Virgin
EVALUATED DATA Virgin
-------------- Virgin
THE EVALUATED DATA MUST BE IN THE ENDF/B FORMAT. HOWEVER IT Virgin
MUST BE LINEAR-LINEAR INTERPOLABLE IN ENERGY-CROSS SECTION Virgin
BETWEEN TABULATED POINTS. SINCE ONLY CROSS SECTIONS (FILE 3 OR 23) Virgin
ARE USED, THIS PROGRAM WILL WORK ON ANY VERSION OF ENDF/B Virgin
(I.E. ENDF/B-I, II, III, IV, V OR VI). Virgin
Virgin
RELATED COMPUTER CODES Virgin
---------------------- Virgin
IN ORDER TO CONVERT ENDF/B DATA TO THE FORM REQUIRED BY THIS CODE Virgin
THE FOLLOWING COMPUTER CODES MAY BE USED, Virgin
Virgin
LINEAR - CONVERT FROM GENERAL ENDF/B INTERPOLATION TO LINEAR- Virgin
LINEAR INTERPOLATION. Virgin
RECENT - ADD THE RESONANCE CONTRIBUTION TO TABULATED BACKGROUND Virgin
CROSS SECTIONS TO OBTAIN LINEAR-LINEAR INTERPOLABLE Virgin
RESULTS. Virgin
SIGMA1 - DOPPLER BROADEN CROSS SECTION TO OBTAIN LINEAR-LINEAR Virgin
INTERPOLABLE RESULTS. Virgin
MIXER - MIX INDIVIDUAL MATERIALS TOGETHER TO DEFINE COMPOSITE Virgin
MIXTURES, E.G., COMBINE MATERIALS TO DEFINE STAINLESS Virgin
STELL. Virgin
Virgin
IN ORDER TO PLOT THE OUTPUT RESULTS OF THIS CODE USE PROGRAM Virgin
PLOTTAB. Virgin
Virgin
COPIES OF ANY OR ALL OF THESE CODES MAY BE OBTAINED FROM D.E. Virgin
CULLEN AT THE ABOVE ADDRESS. Virgin
Virgin
OUTPUT FORMAT Virgin
------------- Virgin
FOR ALL VERSIONS OF THIS PROGRAM PRIOR TO VERSION 92-1 OUTPUT WAS Virgin
IN TABULAR FORM. Virgin
Virgin
FOR VERSION 92-1 AND LATER VERSIONS OF THIS CODE ALL OUTPUT IS IN Virgin
THE PROGRAM PLOTTAB FORMAT TO ALLOW RESULTS TO BE EASILY PLOTTED. Virgin
FOR A COPY OF PROGRAM PLOTTAB CONTACT D.E. CULLEN AT THE ABOVE Virgin
ADDRESS. Virgin
Virgin
TALLY GROUPS Virgin
------------ Virgin
THE TALLY GROUP STRUCTURE MAY BE ANY SET OF MONONTONICALLY Virgin

INCREASING ENERGY BOUNDARIES. THERE MAY BE UP TO 2000 TALLY GROUPS. BY USING THE INPUT PARAMETERS THE USER MAY SPECIFY ANY ARBITRARY TALLY GROUP STRUCTURE OR SELECT ONE OF THE FOLLOWING BUILT-IN GROUP STRUCTURES.

(0) TART 175 GROUPS
(1) ORNL 50 GROUPS
(2) ORNL 126 GROUPS
(3) ORNL 171 GROUPS
(4) SAND-II 620 GROUPS - 1.0e-4 eV UP TO 18 MEV
(5) SAND-II 640 GROUPS - 1.0e-4 eV UP TO 20 MEV
(6) WIMS 69 GROUPS
(7) GAM-I 68 GROUPS
(8) GAM-II 99 GROUPS
(9) MUFT 54 GROUPS
(10) ABBN 28 GROUPS
(11) TART 616 GROUPS TO 20 MeV
(12) TART 700 GROUPS To 1 GeV
(13) SAND-II 665 GROUPS - 1.0e-5 eV UP TO 18 MEV
(14) SAND-II 685 GROUPS - 1.0e-5 eV UP TO 20 MEV
(15) TART 666 GROUPS TO 200 MeV
(16) SAND-II 725 GROUPS - 1.0e-5 eV UP TO 60 MEV
(17) SAND-II 755 GROUPS - 1.0e-5 eV UP TO 150 MEV
(18) SAND-II 765 GROUPS - 1.0e-5 eV UP TO 200 MEV

INCIDENT SPECTRUM

THE INCIDENT SPECTRUM MAY BE ANY TABULATED FUNCTION THAT IS GIVEN BY A SET OF POINTS THAT IS MONOTONICALLY INCREASING IN ENERGY AND LINEAR-LINEAR INTERPOLABLE IN ENERGY-SPECTRUM BETWEEN TABULATED POINTS. THERE IS NO LIMIT TO THE NUMBER OF POINTS USED TO DESCRIBE THE SPECTRUM. THERE ARE FIVE BUILT-IN OPTIONS FOR THE SPECTRUM.

(1) CONSTANT...ENERGY INDEPENDENT (INPUT 0)
(2) 1/E (INPUT 1)
(3) BLACKBODY - PHOTON SPECTRUM
(4) BLACKBODY - ENERGY SPECTRUM (E TIMES THE PHOTON SPECTRUM)
(5) TRANSMITTED SPECTRUM FROM PREVIOUS CASE

NORMALIZATION OF SPECTRUM

ANY INCIDENT SPECTRUM, EITHER READ AS INPUT OR ONE OF THE BUILT-IN SPECTRA, WILL BE NORMALIZED TO UNITY WHEN INTEGRATED OVER THEIR ENTIRE ENERGY RANGE.

TRANSMITTED SPECTRA WILL NOT BE RE-NORMALIZED, SINCE IT ALREADY INCLUDES THE NORMALIZATION OF THE INCIDENT SPECTRUM.

NOTE, INCIDENT SPECTRA IS NORMALIZED TO UNITY OVER THEIR ENTIRE ENERGY RANGE - NOT OVER THE ENERGY RANGE OF THE GROUPS. IF THE ENERGY RANGE OF THE GROUPS IS LESS THAN THAT OF THE SPECTRUM ONLY THAT PORTION OF THE SPECTRUM WILL BE USED AND THIS WILL NOT BE RE-NORMALIZED TO UNITY.

COMPOSITION OF A LAYER

YOU MAY RUN PROBLEMS INVOLVING

1) A LAYER OF UNIFORM DENSITY - DENSITY FOR ATTENUATION IS THAT OF THE TOTAL. DENSITY FOR REACTIONS IS THAT OF THE REACTION.
2) A LAYER OF UNIFORM DENSITY - DENSITY IS THE SUM OF THE TOTAL AND REACTION DENSITIES - THE SUM OF THE CROSS SECTIONS IS USED FOR ATTENUATION AND REACTIONS.
3) A LAYER OF VARYING DENSITY BASED ON A UNIFORM TOTAL DENSITY PLUS A VARIATION BETWEEN 0 AND A MAXIMUM BASED ON THE REACTION DENSITY - 0 AT 0 THICKNESS AND MAXIMUM AT MAXIMUM THICKNESS. IN THIS CASE THE AVERAGE REACTION DENSITY IS EQUAL TO THE INPUT REACTION DENSITY. THE VARIATION IN REACTION DENSITY CAN BE LINEAR, SQUARE OR CUBIC.
4) A LAYER OF VARYING DENSITY BASED ON A TOTAL DENSITY WHICH VARYING FROM MAXIMUM AT 0 THICKNESS TO 0 AT MAXIMUM THICKNESS

PLUS A REACTION DENSITY WHICH VARIES FROM 0 AT 0 THICKNESS TO MAXIMUM AT MAXIMUM THICKNESS. IN THIS CASE THE AVERAGE DENSITY OF THE TOTAL AND REACTION WILL BOTH BE EQUAL TO THE INPUT TOTAL AND REACTION DENSITIES. THE VARIATION IN TOTAL AND REACTION DENSITY CAN BE LINEAR, SQUARE OR CUBIC.

IN THE FIRST CASE THE TWO REQUESTED CROSS SECTIONS ARE CONSIDERED TO BE INDEPENDENT - THE TOTAL CROSS SECTION IS USED TO CALCULATE ATTENUATION AND THE REACTION CROSS SECTION IS USED TO CALCULATE REACTIONS, E.G., TRANSMISSION THROUGH NATURAL URANIUM (THE TOTAL CROSS SECTION SHOULD BE THAT OF NATURAL URANIUM) AND REACTIONS IN A U-235 DETECTOR (THE REACTION CROSS SECTION SHOULD BE THAT OF U-235).

IN THE OTHER THREE CASES THE TWO REQUESTED CROSS SECTIONS ARE TREATED AS TWO CONSTITUENTS OF A MIXTURE OF TWO MATERIALS AND THE TWO CROSS SECTIONS ARE USED BOTH TO DEFINE A TOTAL CROSS SECTION FOR ATTENUATION AND A REACTION CROSS SECTION TO DEFINE REACTIONS. IN THESE CASES THE MIXTURE WILL VARY CONTINUOUSLY, E.G., IN CASE 4) HALF WAY THROUGH THE LAYER THE COMPOSITION WILL BE 1/2 THE MATERIAL DEFINED BY THE TOTAL AND 1/2 THE MATERIAL BASED ON THE REACTION. IN THESE CASES RATHER THAN THINKING OF THE TWO CROSS SECTIONS AS A TOTAL AND REACTION CROSS SECTION, IT IS BETTER TO THINK OF THEM AS THE TOTAL CROSS SECTIONS FOR MATERIALS A AND B AND THE CALCULATED REACTIONS WILL BE BASED ON THESE TWO TOTAL CROSS SECTIONS.

MULTIPLE LAYERS

THIS CODE MAY BE USED TO RUN EITHER A NUMBER OF INDEPENDENT PROBLEMS, EACH INVOLVING TRANSMISSION THROUGH A SINGLE LAYER OF MATERIAL, OR TRANSMISSION THROUGH A NUMBER OF LAYERS ONE AFTER THE OTHER.

IN THE CASE OF MULTIPLE LAYERS, ONE LAYER AFTER ANOTHER, THE TRANSMITTED ENERGY DEPENDENT SPECTRUM IS USED AS THE INCIDENT SPECTRUM FOR THE NEXT LAYER. THERE IS NO LIMIT TO THE NUMBER OF LAYERS WHICH MAY BE USED - EACH LAYER IS TREATED AS A COMPLETELY INDEPENDENT PROBLEM WITH A DEFINED INCIDENT SOURCE, AND AS SUCH THE CYCLE OF TRANSMISSION THROUGH EACH LAYER AND USING THE TRANSMITTED SPECTRUM AS THE INCIDENT SPECTRUM FOR THE NEXT LAYER MAY BE REPEATED ANY NUMBER OF TIMES.

REMEMBER - THE INCIDENT SPECTRUM IS ASSUMED TO BE LINEARLY INTERPOLABLE IN ENERGY AND SPECTRUM BETWEEN THE ENERGIES AT WHICH IT IS TABULATED. THE TRANSMITTED SPECTRUM WILL BE TABULATED AT THE UNION OF ALL ENERGIES OF THE INCIDENT SPECTRUM AND CROSS SECTIONS (TOTAL AND REACTION). IN ORDER TO INSURE THE ACCURACY OF THE RESULT WHEN PERFORMING MULTIPLE LAYER CALCULATION BE SURE TO SPECIFY THE INCIDENT SPECTRUM ON THE FIRST LAYER TO SUFFICIENT DETAIL (ENOUGH ENERGY POINTS CLOSELY SPACED TOGETHER) IN ORDER TO ALLOW THE TRANSMITTED SPECTRUM TO BE ACCURATELY REPRESENTED BY LINEAR INTERPOLATION BETWEEN SUCCESSIVE ENERGY POINTS - THERE IS NO LIMIT TO THE NUMBER OF POINTS ALLOWED IN THE INCIDENT SPECTRUM, SO IF YOU ARE IN DOUBT, SIMPLY USE MORE ENERGY POINTS TO SPECIFY THE INCIDENT SPECTRUM.

RESULT OUTPUT UNITS

FLUX = EXACTLY AS CALCULATED
REACTIONS = 1/CM OR 1/GRAM
AVERAGE CROSS SECTION = 1/CM - MACROSCOPIC UNITS

THICKNESS AND DENSITY

THE UNCOLLIDED CALCULATION ONLY DEPENDS ON THE PRODUCT OF THICKNESS AND DENSITY (I.E. GRAMS PER CM SQUARED). THIS FACT MAY BE USED TO SIMPLIFY INPUT BY ALLOWING THE THICKNESS AND DENSITY TO BE GIVEN EITHER AS CM AND GRAMS/CC RESPECTIVELY

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OR ELSE TO GIVE THICKNESS IN GRAMS/(CM*CM) AND INPUT A                Virgin
DENSITY OF 1.0 - OR IN ANY OTHER CONVENIENT UNITS AS LONG AS          Virgin
THE PRODUCT OF THICKNESS AND DENSITY IS IN THE CORRECT GRAMS          Virgin
PER CENTIMETER SQUARED.                                               Virgin
                                                                      Virgin
GRAMS/(CM*CM) ARE RELATED TO ATOMS/BARN THROUGH THE RELATIONSHIP      Virgin
                                                                      Virgin
GRAMS/(CM*CM)=(ATOMS/BARN)*(GRAMS/MOLE)*(MOLE/ATOM)                   Virgin
                                                                      Virgin
OR...                                                                 Virgin
                                                                      Virgin
GRAMS/(CM*CM)=(ATOMS/BARN)*(ATOMIC WEIGHT)/0.602                      Virgin
                                                                      Virgin
CROSS SECTIONS AT A SPACE POINT AND OPTICAL THICKNESS                 Virgin
-----------------------------------------------------                 Virgin
THIS PROGRAM ALLOWS LAYERS OF EITHER UNIFORM DENSITY OR               Virgin
CONTINUOUSLY VARYING DENSITY. THE DENSITY CAN BE ONE OF THE           Virgin
FOLLOWING FORMS,                                                      Virgin
1) C                    = UNIFORM DENSITY                             Virgin
2) C*2*(X/T)            = LINEAR VARIATION FROM 0 TO C                Virgin
3) C*(2-2*(X/T))        = LINEAR VARIATION FROM C TO 0                Virgin
4) C*3*(X/T)**2         = SQUARE VARIATION FROM 0 TO C                Virgin
5) C*(3-3*(X/T)**2)/2   = SQUARE VARIATION FROM C TO 0                Virgin
6) C*4*(X/T)**3         = CUBIC VARIATION FROM 0 TO C                 Virgin
7) C*(4-4*(X/T)**3)/3   = CUBIC VARIATION FROM C TO 0                 Virgin
                                                                      Virgin
IN ORDER TO CALCULATE REACTIONS AT A POINT THE MICROSCOPIC            Virgin
REACTION CROSS SECTION NEED MERELY BE SCALED BY THESE DENSITIES.      Virgin
                                                                      Virgin
IN ORDER TO CALCULATE TRANSMISSION WE MUST DEFINE THE OPTICAL         Virgin
PATH LENGTH WHICH MAY BE DEFINED BY INTEGRATING EACH OF THE           Virgin
ABOVE DENSITY FORMS TO FIND,                                          Virgin
1) C*X                                                                Virgin
2) C*X*(X/T)                                                          Virgin
3) C*X*(2-(X/T))                                                      Virgin
4) C*X*(X/T)**2                                                       Virgin
5) C*X*(3-(X/T)**2)/2                                                 Virgin
6) C*X*(X/T)**3                                                       Virgin
7) C*X*(4-(X/T)**3))/3                                                Virgin
                                                                      Virgin
IN ORDER TO CALCULATE TRANSMISSION TO A POINT THE MICROSCOPIC         Virgin
TOTAL CROSS SECTION NEED MERELY BE SCALED BY THESE DENSITIES          Virgin
TO DEFINE THE OPTICAL PATH LENGTH.                                    Virgin
                                                                      Virgin
THE VARIATION OF THE DENSITY THROUGH THE LAYER MAY BE DEFINED         Virgin
BY SETTING X = 0 OR X = T TO FIND,                                    Virgin
   X = 0      X = T                                                   Virgin
   -----      -----                                                   Virgin
1) C          C                                                       Virgin
2) 0          2*C                                                     Virgin
3) 2*C        0                                                       Virgin
4) 0          3*C                                                     Virgin
5) 3*C/2      0                                                       Virgin
6) 0          4*C                                                     Virgin
7) 4*C/3      0                                                       Virgin
                                                                      Virgin
THE OPTICAL PATH THROUGH A LAYER OF THICKNESS T MAY BE DEFINED        Virgin
FROM THE ABOVE EXPRESSIONS BY SETTING X=T TO FIND THAT IN ALL         Virgin
CASES THE ANSWER WILL BY C*T. THE CONSTANTS IN THE ABOVE              Virgin
EXPRESSIONS HAVE BEEN INTRODUCED IN ORDER TO FORCE THIS RESULT.       Virgin
WITH THESE FACTORS THE OPTICAL PATH LENGTH THROUGH THE LAYER          Virgin
WILL EXACTLY CORRESPOND TO AN AVERAGE DENSITY CORRESPONDING TO        Virgin
THAT INPUT FOR THE TOTAL AND/OR REACTION, I.E., C CORRESPONDS         Virgin
TO THE INPUT DENSITY.                                                 Virgin
                                                                      Virgin
NOTE - FOR THE SAME OPTICAL PATH LENGTHS THROUGH THE LAYER THE        Virgin
TRANSMISSION WILL BE EXACTLY THE SAME. HOWEVER, VARYING THE           Virgin
DENSITY WILL ALLOW YOU TO MODIFY THE REACTION RATES AT SPECIFIC       Virgin
DEPTHS INTO THE LAYER.                                                Virgin
                                                                      Virgin
COMPUTATION OF INTEGRALS                                              Virgin
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------------------------                                                Virgin
STARTING FROM TOTAL CROSS SECTIONS, REACTION CROSS SECTIONS AND         Virgin
A SOURCE SPECTRUM ALL OF WHICH ARE GIVEN IN TABULAR FORM WITH           Virgin
LINEAR INTERPOLATION BETWEEN TABULATED POINTS ALL REQUIRED              Virgin
INTEGRALS CAN BE DEFINED BY ANALYTICAL EXPRESSIONS INVOLVING            Virgin
NOTHING MORE COMPLICATED THAN EXPONENTIALS. THE INTEGRALS THAT          Virgin
MUST BE EVALUATED ARE OF THE FORM...                                    Virgin
                                                                        Virgin
FLUX                                                                    Virgin
----                                                                    Virgin
(INTEGRAL EK TO EK+1) (S(E)* EXP(-XCT(E)*Z)*DE)                         Virgin
                                                                        Virgin
REACTIONS                                                               Virgin
---------                                                               Virgin
(INTEGRAL EK TO EK+1) (S(E)*XCR(E)*EXP(-XCT(E)*Z)*DE)                   Virgin
                                                                        Virgin
WHERE..                                                                 Virgin
EK TO EK+1 = LONGEST ENERGY INTERVAL OVER WHICH S(E), XCT(E) AND        Virgin
             XCR(E) ARE ALL LINEARLY INTERPOLABLE.                      Virgin
S(E)       = ENERGY DEPENDENT WEIGHTING SPECTRUM                        Virgin
XCR(E)     = REACTION CROSS SECTION                                     Virgin
XCT(E)     = OPTICAL PATH LENGTH (BASED ON TOTAL CROSS SECTION)         Virgin
Z          = MATERIAL THICKNESS                                         Virgin
                                                                        Virgin
S(E), XCR(E) AND XCT(E) ARE ALL ASSUMED TO BE GIVEN IN TABULAR          Virgin
FORM WITH LINEAR INTERPOLATION USED BETWEEN TABULATED POINTS.           Virgin
IN OTHER WORDS BETWEEN TABULATED POINTS EACH OF THESE THREE IS          Virgin
DEFINED BY A FUNCTION OF THE FORM...                                    Virgin
                                                                        Virgin
F(E)=((E - EK)*FK+1 + (EK+1 - E)*FK)/(EK+1 - EK)                        Virgin
                                                                        Virgin
EACH OF THESE THREE CAN BE CONVERTED TO NORMAL FORM BY THE              Virgin
CHANGE OF VARIABLES....                                                 Virgin
                                                                        Virgin
X=(E - 0.5*(EK+1 + EK))/(EK+1 - EK)                                     Virgin
                                                                        Virgin
IN WHICH CASE X WILL VARY FROM -1 (AT EK) TO +1 (AT EK+1) AND           Virgin
EACH FUNCTION REDUCES TO THE NORMAL FORM...                             Virgin
                                                                        Virgin
F(X)=0.5*(FK*(1 - X) + FK+1*(1 + X))                                    Virgin
    =0.5*(FK+1 + FK) + 0.5*(FK+1 - FK)*X                                Virgin
                                                                        Virgin
BY DEFINING THE AVERAGE VALUE AND 1/2 THE CHANGE ACROSS THE             Virgin
INTERVAL.                                                               Virgin
                                                                        Virgin
AVF=0.5*(FK+1 + FK)                                                     Virgin
DF= 0.5*(FK+1 - FK)                                                     Virgin
DE= 0.5*(EK+1 - EK)                                                     Virgin
                                                                        Virgin
EACH OF THE THREE FUNCTIONS REDUCES TO THE SIMPLE FORM...               Virgin
                                                                        Virgin
F(X)=AVF+DF*X                                                           Virgin
                                                                        Virgin
AND THE TWO REQUIRED INTEGRALS REDUCE TO...                             Virgin
                                                                        Virgin
FLUX                                                                    Virgin
----                                                                    Virgin
DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)                                  Virgin
((AVS+DS*X)*EXP(-DXCT*Z*X)*DX)                                          Virgin
                                                                        Virgin
REACTION                                                                Virgin
--------                                                                Virgin
DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)                                  Virgin
((AVS*AVXCR+(AVS*DXCR+AVXCR*DS)*X+DS*DXCR*X*X)*EXP(-DXCT*Z*X)*DX)       Virgin
                                                                        Virgin
WHERE                                                                   Virgin
                                                                        Virgin
AVXCT   = AVERAGE VALUE OF THE TOTAL CROSS SECTION                      Virgin
AVXCR   = AVERAGE VALUE OF THE REACTION CROSS SECTION                   Virgin
AVS     = AVERAGE VALUE OF THE SOURCE                                   Virgin
DXCT    = 1/2 THE CHANGE IN THE TOTAL CROSS SECTION                     Virgin
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DXCR    = 1/2 THE CHANGE IN THE REACTION CROSS SECTION            Virgin
DS      = 1/2 THE CHANGE IN THE SOURCE                            Virgin
DE      = 1/2 THE CHANGE IN THE ENERGY                            Virgin
                                                                  Virgin
NOTE THAT IN THIS FORM THE ENERGY ONLY APPEARS IN FRONT OF THE    Virgin
INTEGRALS AND THE INTEGRALS ARE EXPRESSED ONLY IN TERMS OF THE    Virgin
TABULATED VALUES OF S(E), XCT(E) AND XCR(E). IN PARTICULAR NO     Virgin
DERIVATIVES ARE USED, SO THAT THERE ARE NO NUMERICAL INSTABILITY  Virgin
PROBLEMS IN THE VACINITY OF DISCONTINUITIES IN S(E), XCT(E) OR    Virgin
XCR(E). INDEED, SINCE (EK+1 - EK) APPEARS IN FRONT OF THE INTEGRAL Virgin
POINTS OF DISCONTINUITY AUTOMATICALLY MAKE ZERO CONTRIBUTION TO   Virgin
THE INTEGRALS.                                                    Virgin
                                                                  Virgin
THE REQUIRED INTEGRALS CAN BE EXPRESSED IN TERMS OF THE THREE     Virgin
INTEGRALS IN NORMAL FORM....                                      Virgin
                                                                  Virgin
F(A,N) = (INTEGRAL -1 TO 1) (X**N*EXP(-A*X)*DX), N=0,1 AND 2.     Virgin
                                                                  Virgin
THESE THREE INTEGRALS CAN BE EVALUATED TO FIND...                 Virgin
                                                                  Virgin
N=0                                                               Virgin
---                                                               Virgin
F(A,0) = (EXP(A)-EXP(-A))/A                                       Virgin
                                                                  Virgin
N=1                                                               Virgin
---                                                               Virgin
F(A,1) = ((1-A)*EXP(A)-(1+A)*EXP(-A))/(A*A)                       Virgin
                                                                  Virgin
N=2                                                               Virgin
---                                                               Virgin
F(A,2) = ((2-2*A+A*A)*EXP(A)-(2+2*A+A*A)*EXP(-A))/(A*A*A)         Virgin
                                                                  Virgin
HOWEVER THESE EXPRESSIONS ARE NUMERICALLY UNSTABLE FOR SMALL      Virgin
VALUES OF A. THEREFORE FOR SMALL A THE EXPONENTIAL IN THE         Virgin
INTEGRALS ARE EXPANDED IN A POWER SERIES...                       Virgin
                                                                  Virgin
EXP(-AX)=1.0-(AX)+(AX)**2/2-(AX)**3/6+(AX)**4/24-.....            Virgin
        =(SUM K=0 TO INFINITY) (-AX)**K/(K FACTORIAL)             Virgin
                                                                  Virgin
AND THE INTEGRAL REDUCES TO THE FORM....                          Virgin
                                                                  Virgin
(SUM K=0 TO INFINITY) ((-A)**K/(K FACTORIAL)) *                   Virgin
(INTEGRAL -1 TO 1) (X**(N+K))*DX                                  Virgin
                                                                  Virgin
WHICH CAN BE ANALYTICALLY EVAULATED TO FIND....                   Virgin
(K(N) = K FACTORIAL)                                              Virgin
                                                                  Virgin
N=0                                                               Virgin
---                                                               Virgin
F(A,0) = 2*(1+(A**2)/K(3)+(A**4)/K(5)+(A**6)/K(7)+....            Virgin
                                                                  Virgin
N=1                                                               Virgin
---                                                               Virgin
F(A,1) = -2*A*(2/K(3)+4*(A**2)/K(5)+6*(A**4)/K(7)+8*(A**6)/K(9)+.. Virgin
                                                                  Virgin
N=2                                                               Virgin
---                                                               Virgin
F(A,2) = 2*(2/K(3)+3*4*(A**2)/K(5)+5*6*(A**4)/K(7)+               Virgin
         7*8*(A**6)/K(9)+....                                     Virgin
                                                                  Virgin
THESE EXPANSIONS ARE USED WHEN THE ABSOLUTE VALUE OF A IS LESS    Virgin
THAN 0.1. BY TRUNCATING THE ABOVE SERIES BEFORE A**8 THE ERROR    Virgin
RELATIVE TO THE LEADING TERM OF THE SERIES WILL BE 10**(-10),     Virgin
YIELDING 10 DIGIT ACCURACY.                                       Virgin
                                                                  Virgin
AFTER EVALUATING THE ABOVE FUNCTIONS, EITHER DIRECTLY OR BY USING Virgin
THE EXPANSION THE TWO REQUIRED INTEGRALS CAN BE WRITTEN AS...     Virgin
                                                                  Virgin
FLUX                                                              Virgin
----                                                              Virgin
DE*EXP(-AVXCT*Z)*(AVS*F(A,0) + DS*F(A,1))                         Virgin
```

Virgin

REACTIONS

DE*EXP(-AVXCT*Z)*
(AVS*AVXCR*F(A,0) + (AVS*DXCR+AVXCR*DS)*F(A,1) + DS*DXCR*F(A,2))

INPUT FILES

FILENAME	UNIT	DESCRIPTION
INPUT	2	INPUT LINES
ENDFIN	10	EVALUATED DATA IN ENDF/B FORMAT

OUTPUT FILES

FILENAME	UNIT	DESCRIPTION
OUTPUT	3	OUTPUT LISTING

SCRATCH FILES

FILENAME	UNIT	DESCRIPTION
SCR1	12	REACTION, FLUX AND CROSS SECTION RESULTS (BCD) (SORTED AT END OF RUN AND OUTPUT SEPARATELY)
SCR2	13	TALLY GROUP ENERGY BOUNDARIES (BINARY)
SCR3	14	SOURCE SPECTRUM (BINARY)
SCR4	15	TOTAL CROSS SECTION (BINARY)
SCR5	16	REACTION CROSS SECTION (BINARY)

OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILIO1 AND FILEIO2)

UNIT	FILE NAME	FORMAT
2	VIRGIN.INP	BCD
3	VIRGIN.LST	BCD
10	ENDFB.IN	BCD
11-15	(SCRATCH)	BINARY
16	PLOTTAB.CUR	PLOTTAB OUTPUT FORMAT DATA

INPUT LINES

ANY NUMBER OF CASES MAY BE RUN ONE AFTER THE OTHER. AFTER THE FIRST CASE HAS BEEN RUN THE FOLLOWING CASES MAY USE THE SAME THICKNESSES, GROUP STRUCTURE AND SPECTRUM AS THE PRECEDING CASE. IN ADDITION THE TRANSMITTED SPECTRUM FROM ONE CASE MAY BE USED AS THE INCIDENT SPECTRUM IN THE NEXT CASE, TO ALLOW MULTIPLE LAYERS OF DIFFERENT MATERIALS.

LINE	COLS.	FORMAT	DESCRIPTION
1	1-60		ENDF/B INPUT DATA FILENAME (STANDARD OPTION = ENDFB.IN)

LEAVE THE DEFINITION OF THE FILENAMES BLANK - THE PROGRAM WILL THEN USE STANDARD FILENAMES.

2-3	1-72	18A4	TWO LINE TITLE DESCRIBING PROBLEM
4	1- 6	I6	ZA (1000*Z+A) OF TARGET FOR TOTAL
	7-11	I5	MT OF TOTAL
	12-22	E11.4	DENSITY FOR TOTAL
	23-28	I6	ZA (1000*Z+A) OF TARGET FOR REACTION
	29-33	I5	MT OF REACTION = 0 - NO REACTION CALCULATION (ONLY FLUX). = GREATER THAN 0 - CALCULATE REACTIONS.
	34-44	E11.4	DENSITY FOR REACTION
	45-50	I6	NUMBER OF TARGET THICKNESSES = GREATER THAN 0 = READ FROM INPUT (1 TO 2000 ALLOWED) = 0 = SAME AS LAST CASE
	51-55	I5	NUMBER OF TALLY GROUPS

			(REMEMBER NUMBER OF GROUP BOUNDARIES	Virgin
			IS ONE MORE THAN THE NUMBER OF GROUPS)	Virgin
			UP TO 2000 GROUPS ARE ALLOWED	Virgin
			BUILT-IN GROUP STRUCTURES.	Virgin
			= GREATER THAN 0 = READ FROM INPUT	Virgin
			= 0 TART 175 GROUPS	Virgin
			= -1 ORNL 50 GROUPS	Virgin
			= -2 ORNL 126 GROUPS	Virgin
			= -3 ORNL 171 GROUPS	Virgin
			= -4 SAND-II 620 GROUPS..1.0e-4 eV TO 18 MEV	Virgin
			= -5 SAND-II 640 GROUPS..1.0e-4 eV TO 20 MEV	Virgin
			= -6 WIMS 69 GROUPS	Virgin
			= -7 GAM-I 68 GROUPS	Virgin
			= -8 GAM-II 99 GROUPS	Virgin
			= -9 MUFT 54 GROUPS	Virgin
			=-10 ABBN 28 GROUPS	Virgin
			=-11 TART 616 GROUPS TO 20 MeV	Virgin
			=-12 TART 700 GROUPS TO 1 GeV	Virgin
			=-13 SAND-II 665 GROUPS..1.0e-5 eV TO 18 MEV	Virgin
			=-14 SAND-II 685 GROUPS..1.0e-5 eV TO 20 MEV	Virgin
			=-15 TART 666 GROUPS TO 200 MeV	Virgin
			=-16 SAND-II 725 GROUPS..1.0e-5 eV TO 60 MEV	Virgin
			=-17 SAND-II 755 GROUPS..1.0e-5 eV TO 150 MEV	Virgin
			=-18 SAND-II 765 GROUPS..1.0e-5 eV TO 200 MEV	Virgin
	56-60	I5	NUMBER OF POINTS IN SOURCE SPECTRUM	Virgin
			(MUST BE AT LEAST TWO POINTS)	Virgin
			= GREATER THAN 1 = READ FROM INPUT	Virgin
			= 0 = SAME AS LAST CASE	Virgin
			= -1 = CONSTANT (ENERGY INDEPENDENT)	Virgin
			= -2 = 1/E	Virgin
			= -3 = BLACKBODY - PHOTON SPECTRUM	Virgin
			= -4 = BLACKBODY - ENERGY SPECTRUM	Virgin
			= -5 = TRANSMITTED SPECTRUM FROM LAST CASE	Virgin
			NOTE, ALL SPECTRA, EXCEPT THE TRANSMITTED	Virgin
			SPECTRUM FROM THE LAST CASE, WILL BE	Virgin
			NORMALIZED SUCH THAT ITS INTEGRAL OVER	Virgin
			ENERGY WILL BE UNITY.	Virgin
	61-64	1X,3I1	SPATIALLY DEPENDENT OUTOUT	Virgin
			= 0 = NO	Virgin
			= 1 = YES	Virgin
			FOR THE 3 QUANTITIES	Virgin
			COLUMN 67 FLUX	Virgin
			68 REACTIONS	Virgin
			69 AVERAGE CROSS SECTION	Virgin
	65-65	I1	ENERGY DEPENDENT OUTOUT	Virgin
			= 0 = NONE	Virgin
			= 1 = INCIDENT SPECTRUM	Virgin
			= 2 = TRANSMITTED SPECTRUM	Virgin
			= 3 = INCIDENT REACTIONS	Virgin
			= 4 = TRANSMIITED REACTIONS	Virgin
			= 5 = TOTAL CROSS SECTION	Virgin
			= 6 = REACTION CROSS SECTION	Virgin
5	1-11	E11.4	BLACKBODY TEMPERATURE IN eV	Virgin
	12-22	E11.4	FLUX NORMALIZATION	Virgin
	23-33	E11.4	REACTION NORMALIZATION	Virgin
			CALCULATIONS WILL BE BASED ON THE SPECTRUM	Virgin
			AND CROSS SECTIONS AS READ. AT OUTPUT THE	Virgin
			RESULTS WILL BE MULTIPLIED BY THESE	Virgin
			NORMALIZATION FACTORS.	Virgin
	34-44	I11	DENSITY PROFILE	Virgin
			= 0 - UNIFORM - BASED ON TOTAL DENSITY	Virgin
			= 1 - UNIFORM - TOTAL + REACTION DENSITY	Virgin
			= 2 - TOTAL + LINEAR REACTION	Virgin
			= 3 - LINEAR (TOTAL + REACTION)	Virgin
			= 4 - TOTAL + SQUARE REACTION	Virgin
			= 5 - SQUARE (TOTAL + REACTION)	Virgin
			= 6 - TOTAL + CUBIC REACTION	Virgin
			= 7 - CUBIC (TOTAL + REACTION)	Virgin
6-N	1-66	6E11.4	TARGET THICKNESSES IN CM	Virgin
			IF SAME AS LAST CASE THIS SECTION IS NOT	Virgin
			INCLUDED IN THE INPUT.	Virgin

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     VARY   1-66  6E11.4  TALLY GROUP ENERGY BOUNDARIES                Virgin
                          (NUMBER OF BOUNDARIES IS ONE MORE THAN       Virgin
                          THE NUMBER OF TALLY GROUPS)                  Virgin
                          IF THE STANDARD OPTION (-14 TO 0) IS         Virgin
                          SELECTED THIS SECTION IS NOT INCLUDED        Virgin
                          IN THE INPUT                                 Virgin
     VARY   1-66  6E11.4  SOURCE SPECTRUM IN ENERGY (eV)-SOURCE PAIRS  Virgin
                          (MUST BE AT LEAST TWO POINTS)                Virgin
                          IF STANDARD OPTION (-5 TO 0) IS SELECTED THIS Virgin
                          SECTION IS NOT INCLUDED IN THE INPUT         Virgin
                                                                       Virgin
     ANY NUMBER OF CASES MAY BE RUN ONE AFTER ANOTHER.                 Virgin
                                                                       Virgin
     EXAMPLE INPUT NO. 1                                               Virgin
     -------------------                                               Virgin
     CALCULATE THE UNCOLLIDED FLUX AND CAPTURE (MT=102) THROUGH        Virgin
     30 CM OF IRON (DENSITY 7.87 G/CC). TALLY THE RESULTS USING        Virgin
     THE TART 175 GROUP STRUCTURE. THE SOURCE WILL BE CONSTANT         Virgin
     FROM 1 KEV TO 20 MEV. USE THE STANDARD ENDF/B INPUT DATA          Virgin
     FILENAME.                                                         Virgin
                                                                       Virgin
     ENDFB.IN                                                          Virgin
     IRON 0 TO 30 CM THICK.                                            Virgin
     CONSTANT SOURCE FROM 1 KEV TO 20 MEV.                             Virgin
      26000    1 7.87000+ 0 26000  102 7.87000+ 0     2    0    2 1100  Virgin
      0.00000+ 0 1.00000+ 0 1.00000+ 0          0 0.00000+00            Virgin
      0.00000+00 3.00000+01                                            Virgin
      1.0000E+03 1.0000E+00 2.0000E+07 1.0000E+00                      Virgin
                                                                       Virgin
     EXAMPLE INPUT NO. 2                                               Virgin
     -------------------                                               Virgin
     CALCULATE THE UNCOLLIDED PHOTON FLUX THROUGH A MIXTURE OF SILICON  Virgin
     AND IRON FOR 100 MEV PHOTONS INCIDENT. THE TRANSMISSION WILL BE   Virgin
     CALCULATED FOR 21 THICKNESSES VARYING BETWEEN 0 AND 1 CM. THERE   Virgin
     WILL BE ONLY 1 TALLY GROUP SPANNING A VERY NARROW ENERGY RANGE    Virgin
     NEAR 100 MEV, AND THE SOURCE SPECTRUM WILL BE CONSTANT OVER THE   Virgin
     SAME ENERGY RANGE. USE THE STANDARD ENDF/B INPUT DATA FILENAME    Virgin
     BY LEAVING THE FIRST INPUT LINE BLANK.                            Virgin
                                                                       Virgin
     (THIS IS A BLANK LINE TO USE THE STANDARD INPUT FILENAME)         Virgin
     100 MEV PHOTONS                                                   Virgin
     SILICON + 5 % IRON                                                Virgin
      14000  521 2.30000+ 0 26000  521 1.15000- 1    21    1    2 1000  Virgin
      0.00000+ 0 1.00000+ 0 1.00000+ 0          1 0.00000+00            Virgin
      0.00000+00 5.00000-01 1.00000+00 1.50000+00 2.00000+00 2.50000+00 Virgin
      3.00000+00 3.50000+00 4.00000+00 4.50000+00 5.00000+00 5.50000+00 Virgin
      6.00000+00 6.50000+00 7.00000+00 7.50000+00 8.00000+00 8.50000+00 Virgin
      9.00000+00 9.50000+00 1.00000+01                                 Virgin
      9.99000+ 7 1.00100+ 8                                            Virgin
      9.99000+ 7 1.00000+ 4 1.00100+ 8 1.00000+ 4                      Virgin
                                                                       Virgin
    ================================================================== Virgin
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