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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 12,000  Virgin
                                                                        Virgin
     OWNED, MAINTAINED AND DISTRIBUTED BY                               Virgin
     -----------------------------------                                Virgin
     THE NUCLEAR DATA SECTION                                           Virgin
     INTERNATIONAL ATOMIC ENERGY AGENCY                                 Virgin
     P.O. BOX 100                                                       Virgin
     A-1400, VIENNA, AUSTRIA                                            Virgin
     EUROPE                                                             Virgin
                                                                        Virgin
     ORIGINALLY WRITTEN BY                                              Virgin
     -----------------------------------                                Virgin
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                                                                    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         Virgin
GROUPS. BY USING THE INPUT PARAMETERS THE USER MAY SPECIFY ANY      Virgin
ARBITRARY TALLY GROUP STRUCTURE OR SELECT ONE OF THE FOLLOWING      Virgin
BUILT-IN GROUP STRUCTURES.                                          Virgin
                                                                    Virgin
 (1) TART 175 GROUPS (INPUT  0)                                     Virgin
 (2) ORNL  50 GROUPS (INPUT -1)                                     Virgin
 (3) ORNL 126 GROUPS (INPUT -2)                                     Virgin
 (4) ORNL 171 GROUPS (INPUT -3)                                     Virgin
 (5) SAND-II 620 GROUPS...UP TO 18 MEV (INPUT -4)                   Virgin
 (6) SAND-II 640 GROUPS...UP TO 20 MEV (INPUT -5)                   Virgin
 (7) WIMS 69 GROUPS (INPUT -6)                                      Virgin
 (8) GAM-I 68 GROUPS (INPUT -7)                                     Virgin
 (9) GAM-II 99 GROUPS (INPUT -8)                                    Virgin
(10) MUFT 54 GROUPS (INPUT -9)                                      Virgin
(11) ABBN 28 GROUPS (INPUT -10)                                     Virgin
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Virgin

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

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MATERIALS A AND B AND THE CALCULATED REACTIONS WILL BE BASED       Virgin
ON THESE TWO TOTAL CROSS SECTIONS.                                 Virgin
                                                                   Virgin
MULTIPLE LAYERS                                                    Virgin
--------------                                                     Virgin
THIS CODE MAY BE USED TO RUN EITHER A NUMBER OF INDEPENDENT        Virgin
PROBLEMS, EACH INVOLVING TRANSMISSION THROUGH A SINGLE LAYER OF    Virgin
MATERIAL, OR TRANSMISSION THROUGH A NUMBER OF LAYERS ONE AFTER     Virgin
THE OTHER.                                                         Virgin
                                                                   Virgin
IN THE CASE OF MULTIPLE LAYERS, ONE LAYER AFTER ANOTHER, THE       Virgin
TRANSMITTED ENERGY DEPENDENT SPECTRUM IS USED AS THE INCIDENT      Virgin
SPECTRUM FOR THE NEXT LAYER. THERE IS NO LIMIT TO THE NUMBER       Virgin
OF LAYERS WHICH MAY BE USED - EACH LAYER IS TREATED AS A           Virgin
COMPLETELY INDEPENDENT PROBLEM WITH A DEFINED INCIDENT SOURCE,     Virgin
AND AS SUCH THE CYCLE OF TRANSMISSION THROUGH EACH LAYER AND       Virgin
USING THE TRANSMITTED SPECTRUM AS THE INCIDENT SPECTRUM FOR THE    Virgin
NEXT LAYER MAY BE REPEATED ANY NUMBER OF TIMES.                    Virgin
                                                                   Virgin
REMEMBER - THE INCIDENT SPECTRUM IS ASSUMED TO BE LINEARLY         Virgin
INTERPOLABLE IN ENERGY AND SPECTRUM BETWEEN THE ENERGIES AT        Virgin
WHICH IT IS TABULATED. THE TRANSMITTED SPECTRUM WILL BE TABULATED  Virgin
AT THE UNION OF ALL ENERGIES OF THE INCIDENT SPECTRUM AND CROSS     Virgin
SECTIONS (TOTAL AND REACTION). IN ORDER TO INSURE THE ACCURACY     Virgin
OF THE RESULT WHEN PERFORMING MULTIPLE LAYER CALCULATION BE SURE   Virgin
TO SPECIFY THE INCIDENT SPECTRUM ON THE FIRST LAYER TO SUFFICIENT  Virgin
DETAIL (ENOUGH ENERGY POINTS CLOSELY SPACED TOGETHER) IN ORDER TO  Virgin
ALLOW THE TRANSMITTED SPECTRUM TO BE ACCURATELY REPRESENTED BY     Virgin
LINEAR INTERPOLATION BETWEEN SUCCESSIVE ENERGY POINTS - THERE IS   Virgin
NO LIMIT TO THE NUMBER OF POINTS ALLOWED IN THE INCIDENT SPECTRUM, Virgin
SO IF YOU ARE IN DOUBT, SIMPLY USE MORE ENERGY POINTS TO SPECIFY   Virgin
THE INCIDENT SPECTRUM.                                             Virgin
                                                                   Virgin
RESULT OUTPUT UNITS                                                Virgin
------------------                                                 Virgin
FLUX      = EXACTLY AS CALCULATED                                  Virgin
REACTIONS = 1/CM OR 1/GRAM                                         Virgin
AVERAGE   = 1/CM - MACROSCOPIC UNITS                               Virgin
CROSS                                                              Virgin
SECTION                                                            Virgin
                                                                   Virgin
THICKNESS AND DENSITY                                              Virgin
--------------------                                               Virgin
THE UNCOLLIDED CALCULATION ONLY DEPENDS ON THE PRODUCT OF          Virgin
THICKNESS AND DENSITY (I.E. GRAMS PER CM SQUARED). THIS FACT       Virgin
MAY BE USED TO SIMPLIFY INPUT BY ALLOWING THE THICKNESS AND        Virgin
DENSITY TO BE GIVEN EITHER AS CM AND GRAMS/CC RESPECTIVELY         Virgin
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
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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
------------------------                                            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
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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
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
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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                                                            Virgin
---------                                                            Virgin
DE*EXP(-AVXCT*Z)*                                                    Virgin
(AVS*AVXCR*F(A,0) + (AVS*DXCR+AVXCR*DS)*F(A,1) + DS*DXCR*F(A,2))     Virgin
                                                                     Virgin
INPUT FILES                                                          Virgin
-----------                                                          Virgin
FILENAME  UNIT  DESCRIPTION                                          Virgin
--------  ----  -----------                                          Virgin
INPUT       2   INPUT LINES                                          Virgin
ENDFIN     10   EVALUATED DATA IN ENDF/B FORMAT                      Virgin
                                                                     Virgin
OUTPUT FILES                                                         Virgin
------------                                                         Virgin
FILENAME  UNIT  DESCRIPTION                                          Virgin
--------  ----  -----------                                          Virgin
OUTPUT      3   OUTPUT LISTING                                       Virgin
                                                                     Virgin
SCRATCH FILES                                                        Virgin
-------------                                                        Virgin
FILENAME  UNIT  DESCRIPTION                                          Virgin
--------  ----  -----------                                          Virgin
SCR1       12   REACTION, FLUX AND CROSS SECTION RESULTS (BCD)       Virgin
```

```
                (SORTED AT END OF RUN AND OUTPUT SEPARATELY)      Virgin
 SCR2       13   TALLY GROUP ENERGY BOUNDARIES (BINARY)            Virgin
 SCR3       14   SOURCE SPECTRUM (BINARY)                          Virgin
 SCR4       15   TOTAL CROSS SECTION (BINARY)                      Virgin
 SCR5       16   REACTION CROSS SECTION (BINARY)                   Virgin
                                                                   Virgin
 OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILIO1 AND FILEIO2)  Virgin
 ----------------------------------------------------------------  Virgin
 UNIT  FILE NAME   FORMAT                                          Virgin
 ----  ----------  ------                                          Virgin
   2   VIRGIN.INP   BCD                                          Virgin
   3   VIRGIN.LST   BCD                                          Virgin
  10   ENDFB.IN     BCD                                          Virgin
11-15  (SCRATCH)   BINARY                                        Virgin
  16   PLOTTAB.CUR PLOTTAB OUTPUT FORMAT DATA                    Virgin
                                                                   Virgin
 INPUT LINES                                                       Virgin
 -----------                                                       Virgin
 ANY NUMBER OF CASES MAY BE RUN ONE AFTER THE OTHER. AFTER THE     Virgin
 FIRST CASE HAS BEEN RUN THE FOLLOWING CASES MAY USE THE SAME      Virgin
 THICKNESSES, GROUP STRUCTURE AND SPECTRUM AS THE PRECEDING CASE.  Virgin
 IN ADDITION THE TRANSMITTED SPECTRUM FROM ONE CASE MAY BE USED    Virgin
 AS THE INCIDENT SPECTRUM IN THE NEXT CASE, TO ALLOW MULTIPLE      Virgin
 LAYERS OF DIFFERENT MATERIALS.                                    Virgin
                                                                   Virgin
 LINE  COLS.  FORMAT  DESCRIPTION                                  Virgin
 ----  -----  ------  ----------                                  Virgin
    1   1-60   ENDF/B INPUT DATA FILENAME                         Virgin
                 (STANDARD OPTION = ENDFB.IN)                      Virgin
                                                                   Virgin
 LEAVE THE DEFINITION OF THE FILENAMES BLANK - THE PROGRAM WILL    Virgin
 THEN USE STANDARD FILENAMES.                                      Virgin
                                                                   Virgin
  2-3   1-72   18A4   TWO LINE TITLE DESCRIBING PROBLEM           Virgin
    4   1- 6    I6    ZA (1000*Z+A) OF TARGET FOR TOTAL           Virgin
        7-11    I5    MT OF TOTAL                                 Virgin
       12-22   E11.4  DENSITY FOR TOTAL                          Virgin
       23-28    I6    ZA (1000*Z+A) OF TARGET FOR REACTION        Virgin
       29-33    I5    MT OF REACTION                              Virgin
                      = 0 - NO REACTION CALCULATION (ONLY FLUX).  Virgin
                      = GREATER THAN 0 - CALCULATE REACTIONS.     Virgin
       34-44   E11.4  DENSITY FOR REACTION                       Virgin
       45-50    I6    NUMBER OF TARGET THICKNESSES                Virgin
                      = GREATER THAN 0 = READ FROM INPUT          Virgin
                        (1 TO 2000 ALLOWED)                       Virgin
                      =  0 = SAME AS LAST CASE                    Virgin
       51-55    I5    NUMBER OF TALLY GROUPS                      Virgin
                      (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 SAME AS LAST CASE                      Virgin
                      = -1 TART 175 GROUPS                        Virgin
                      = -2 ORNL  50 GROUPS                        Virgin
                      = -3 ORNL 126 GROUPS                        Virgin
                      = -4 ORNL 171 GROUPS                        Virgin
                      = -5 SAND-II 620 GROUPS..UP TO 18 MEV.      Virgin
                      = -6 SAND-II 640 GROUPS..UP TO 20 MEV.      Virgin
                      = -7 WIMS 69 GROUPS                         Virgin
                      = -8 GAM-I 68 GROUPS                        Virgin
                      = -9 GAM-II 99 GROUPS                       Virgin
                      =-10 MUFT 54 GROUPS                         Virgin
                      =-11 ABBN 28 GROUPS                         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
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 (-11 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
```