```
======================================================================= 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
                                                                        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
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PURPOSE

THIS PROGRAM IS DESIGNED TO CALCULATE UNCOLLIDED (I.E. VIRGIN) FLUX AND REACTIONS DUE TO TRANSMISSION OF A MONODIRECTIONAL BEAM OF NEUTRONS THROUGH ANY THICKNESS OF MATERIAL. IN ORDER TO SIMULATE AN EXPERIMENTAL MEASUREMENT THE RESULTS ARE GIVEN AS INTEGRALS OVER ENERGY TALLY GROUPS (AS OPPOSED TO POINTWISE IN ENERGY). BY TAKING THE RATIO OF REACTIONS TO FLUX IN EACH GROUP AN EQUIVALENT SPATIALLY DEPENDENT GROUP AVERAGED CROSS SECTION IS CALCULATED BY THE PROGRAM.

EVALUATED DATA

THE EVALUATED DATA MUST BE IN THE ENDF/B FORMAT. HOWEVER IT MUST BE LINEAR-LINEAR INTERPOLABLE IN ENERGY-CROSS SECTION BETWEEN TABULATED POINTS. SINCE ONLY CROSS SECTIONS (FILE 3 OR 23) ARE USED, THIS PROGRAM WILL WORK ON ANY VERSION OF ENDF/B (I.E. ENDF/B-I, II, III, IV, V OR VI).

RELATED COMPUTER CODES

IN ORDER TO CONVERT ENDF/B DATA TO THE FORM REQUIRED BY THIS CODE THE FOLLOWING COMPUTER CODES MAY BE USED,

LINEAR - CONVERT FROM GENERAL ENDF/B INTERPOLATION TO LINEAR-LINEAR INTERPOLATION.
RECENT - ADD THE RESONANCE CONTRIBUTION TO TABULATED BACKGROUND CROSS SECTIONS TO OBTAIN LINEAR-LINEAR INTERPOLABLE RESULTS.
SIGMA1 - DOPPLER BROADEN CROSS SECTION TO OBTAIN LINEAR-LINEAR INTERPOLABLE RESULTS.
MIXER - MIX INDIVIDUAL MATERIALS TOGETHER TO DEFINE COMPOSITE MIXTURES, E.G., COMBINE MATERIALS TO DEFINE STAINLESS STELL.

IN ORDER TO PLOT THE OUTPUT RESULTS OF THIS CODE USE PROGRAM PLOTTAB.

COPIES OF ANY OR ALL OF THESE CODES MAY BE OBTAINED FROM D.E. CULLEN AT THE ABOVE ADDRESS.

OUTPUT FORMAT

FOR ALL VERSIONS OF THIS PROGRAM PRIOR TO VERSION 92-1 OUTPUT WAS IN TABULAR FORM.

FOR VERSION 92-1 AND LATER VERSIONS OF THIS CODE ALL OUTPUT IS IN THE PROGRAM PLOTTAB FORMAT TO ALLOW RESULTS TO BE EASILY PLOTTED. FOR A COPY OF PROGRAM PLOTTAB CONTACT D.E. CULLEN AT THE ABOVE ADDRESS.

TALLY GROUPS

THE TALLY GROUP STRUCTURE MAY BE ANY SET OF MONONTONICALLY 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.

(1) TART 175 GROUPS (INPUT 0)
(2) ORNL 50 GROUPS (INPUT -1)
(3) ORNL 126 GROUPS (INPUT -2)
(4) ORNL 171 GROUPS (INPUT -3)
(5) SAND-II 620 GROUPS...UP TO 18 MEV (INPUT -4)
(6) SAND-II 640 GROUPS...UP TO 20 MEV (INPUT -5)
(7) WIMS 69 GROUPS (INPUT -6)
(8) GAM-I 68 GROUPS (INPUT -7)
(9) GAM-II 99 GROUPS (INPUT -8)
(10) MUFT 54 GROUPS (INPUT -9)
(11) ABBN 28 GROUPS (INPUT -10)

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 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
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
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.

AVF=0.5*(FK+1 + FK)
DF= 0.5*(FK+1 - FK)
DE= 0.5*(EK+1 - EK)

EACH OF THE THREE FUNCTIONS REDUCES TO THE SIMPLE FORM...

F(X)=AVF+DF*X

AND THE TWO REQUIRED INTEGRALS REDUCE TO...

FLUX

DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)
((AVS+DS*X)*EXP(-DXCT*Z*X)*DX)

REACTION

DE*EXP(-AVXCT*Z) * (INTEGRAL -1 TO +1)
((AVS*AVXCR+(AVS*DXCR+AVXCR*DS)*X+DS*DXCR*X*X)*EXP(-DXCT*Z*X)*DX)

WHERE

AVXCT   = AVERAGE VALUE OF THE TOTAL CROSS SECTION
AVXCR   = AVERAGE VALUE OF THE REACTION CROSS SECTION
AVS   = AVERAGE VALUE OF THE SOURCE
DXCT   = 1/2 THE CHANGE IN THE TOTAL CROSS SECTION
DXCR   = 1/2 THE CHANGE IN THE REACTION CROSS SECTION
DS   = 1/2 THE CHANGE IN THE SOURCE
DE   = 1/2 THE CHANGE IN THE ENERGY

NOTE THAT IN THIS FORM THE ENERGY ONLY APPEARS IN FRONT OF THE INTEGRALS AND THE INTEGRALS ARE EXPRESSED ONLY IN TERMS OF THE TABULATED VALUES OF S(E), XCT(E) AND XCR(E). IN PARTICULAR NO DERIVATIVES ARE USED, SO THAT THERE ARE NO NUMERICAL INSTABILITY PROBLEMS IN THE VACINITY OF DISCONTINUITIES IN S(E), XCT(E) OR XCR(E). INDEED, SINCE (EK+1 - EK) APPEARS IN FRONT OF THE INTEGRAL POINTS OF DISCONTINUITY AUTOMATICALLY MAKE ZERO CONTRIBUTION TO THE INTEGRALS.

THE REQUIRED INTEGRALS CAN BE EXPRESSED IN TERMS OF THE THREE INTEGRALS IN NORMAL FORM....

F(A,N) = (INTEGRAL -1 TO 1) (X**N*EXP(-A*X)*DX), N=0,1 AND 2.

THESE THREE INTEGRALS CAN BE EVALUATED TO FIND...

N=0

F(A,0) = (EXP(A)-EXP(-A))/A

N=1

F(A,1) = ((1-A)*EXP(A)-(1+A)*EXP(-A))/(A*A)

N=2

F(A,2) = ((2-2*A+A*A)*EXP(A)-(2+2*A+A*A)*EXP(-A))/(A*A*A)

HOWEVER THESE EXPRESSIONS ARE NUMERICALLY UNSTABLE FOR SMALL VALUES OF A. THEREFORE FOR SMALL A THE EXPONENTIAL IN THE INTEGRALS ARE EXPANDED IN A POWER SERIES...

```
                                                                    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
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 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
```

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                        (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
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     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
```