```
=========================================================================== Sixpak
                                                                            Sixpak
     PROGRAM SIXPAK                                                         Sixpak
     ==============                                                         Sixpak
     VERSION 92-1 (JANUARY 1992)                                            Sixpak
     VERSION 92-2 (FEBRUARY 1992)*INCREASED CORE ALLOCATION TO              Sixpak
                                  ACCOMMODATE JEF AND EFF EVALUATIONS.      Sixpak
     VERSION 92-3 (APRIL 1992)   *ADDED ADDITIONAL DATA TESTS.              Sixpak
     VERSION 92-4 (SEPT. 1992)   *CORRECTED KALBACH-MANN CALCULATIONS.      Sixpak
                                 *FOR PHOTON PRODUCTION OUTPUT MF=12        Sixpak
                                  (MULTIPLICITY), MF=14 (ISOTROPIC          Sixpak
                                  ANGULAR DISTRIBUTIONS) AND MF=15          Sixpak
                                  (SPECTRA) - PREVIOUSLY ONLY MF=15.        Sixpak
                                 *FIRST ORDER CORRECTIONS TRANSFORMING      Sixpak
                                  CENTER-OF-MASS SPECTRA TO LAB SYSTEM      Sixpak
                                  FOR OUTPUT IN MF=5                        Sixpak
                                 *CORRECTED ISOTROPIC ANGULAR               Sixpak
                                  DISTRIBUTION FLAG (LI)                    Sixpak
     VERSION 94-1 (JANUARY 1994) *VARIABLE ENDF/B INPUT DATA FILENAME       Sixpak
                                  TO ALLOW ACCESS TO FILE STRUCTURES        Sixpak
                                  (WARNING - INPUT PARAMETER FORMAT         Sixpak
                                  HAS BEEN CHANGED)                         Sixpak
                                 *CLOSE ALL FILES BEFORE TERMINATING        Sixpak
                                  (SEE, SUBROUTINE ENDIT)                   Sixpak
                                 *INCREASED MAXIMUM TABLE SIZE FROM         Sixpak
                                  2000 TO 6000.                             Sixpak
     VERSION 96-1 (JANUARY 1996) *COMPLETE RE-WRITE                         Sixpak
                                 *IMPROVED COMPUTER INDEPENDENCE            Sixpak
                                 *ALL DOUBLE PRECISION                      Sixpak
                                 *ON SCREEN OUTPUT                          Sixpak
                                 *UNIFORM TREATMENT OF ENDF/B I/O           Sixpak
                                 *IMPROVED OUTPUT PRECISION                 Sixpak
     VERSION 99-1 (MARCH 1999)   *CORRECTED CHARACTER TO FLOATING           Sixpak
                                  POINT READ FOR MORE DIGITS                Sixpak
                                 *UPDATED TEST FOR ENDF/B FORMAT            Sixpak
                                  VERSION BASED ON RECENT FORMAT CHANGE     Sixpak
                                 *GENERAL IMPROVEMENTS BASED ON             Sixpak
                                  USER FEEDBACK                             Sixpak
     VERSION 99-2 (JUNE 1999)    *ASSUME ENDF/B-VI, NOT V, IF MISSING       Sixpak
                                  MF=1, MT-451.                             Sixpak
     VERS. 2000-1 (FEBRUARY 2000)*GENERAL IMPROVEMENTS BASED ON             Sixpak
                                  USER FEEDBACK                             Sixpak
     VERS. 2002-1 (JANUARY 2002) *CORRECTED ANGULAR DISTRIBUTION (MF=4)     Sixpak
                                  OUTPUT TO INSURE USED FIELDS ARE 0        Sixpak
                  (MAY 2002)     *OPTIONAL INPUT PARAMETERS                 Sixpak
                  (NOV. 2002)    *EXTENDED TO ALLOW CHARGED PARTICLE        Sixpak
                                  ANGULAR DISTRIBUTION IN MF=4 -            Sixpak
                                  WARNING - STRICTLY SPEAKING THIS IS       Sixpak
                                  NOT LEGAL, SINCE MF=4 IS SUPPOSED TO      Sixpak
                                  BE USED ONLY FOR NEUTRON ANGULAR          Sixpak
                                  DISTRIBUTIONS - BUT WHERE MT MAKES        Sixpak
                                  IT OBVIOUS THAT THE OUTGOING PARTICLE     Sixpak
                                  IS NOT A NEUTRON HOPEFULLY IT WILL        Sixpak
                                  NOT CAUSE A PROBLEM IF MF=4 IS USED       Sixpak
                                  FOR CHARGED PARTICLES.                    Sixpak
     VERS. 2004-1 (MARCH 2004)   *ADDED INCLUDE FOR COMMON                  Sixpak
                                 *INCREASED MAXIMUM TABLE SIZE FROM         Sixpak
                                  6,000 TO 12,000.                          Sixpak
                                 *ADDED DUMMY A FOR ELEMENTS                Sixpak
                                 *CORRECTED OUTPUT INTERPOLATON LAWS        Sixpak
     VERS. 2007-1 (JAN.  2007)   *CHECKED AGAINST ALL ENDF/B-VII.           Sixpak
                                 *INCREASED MAXIMUM TABLE SIZE FROM         Sixpak
                                  12,000 TO 120,000.                        Sixpak
```

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VERS. 2007-2 (DEC.  2007)   *72 CHARACTER FILE NAMES.                Sixpak
VERS. 2010-1 (Apr.  2010)   *General update based on user feedback  Sixpak
VERS. 2011-1 (May   2011)   *Added MF/MT=9/5 yield output starting  Sixpak
                             from  MF/MT=6/5 distributions.         Sixpak
                            *Increased maximum Legendre order from  Sixpak
                             30 to 1,000 - WARNING - using more     Sixpak
                             than 30 results in NONSENSE = NOISE!!  Sixpak
VERS. 2012-1 (Oct.  2012)   *Increased max. point count to 500,000  Sixpak
                            *Added CODENAME                         Sixpak
                            *32 and 64 bit Compatible               Sixpak
                            *Added ERROR stop                       Sixpak
                            *For photons, combine discrete and      Sixpak
                             continuum into tabulated increasing    Sixpak
                             energy order.                          Sixpak
                            *Check energy output order increasing.  Sixpak
                             Print WARNING if not increasing - do   Sixpak
                             not STOP- stopping would prevent ALL   Sixpak
                             output - the user may not be at all    Sixpak
                             interested in the BAD data, but may    Sixpak
                             be interested in other output data     Sixpak
                             that is o.k.                           Sixpak
VERS. 2015-1 (Jan.  2015)   *Extended OUT9.                         Sixpak
                            *Replaced ALL 3 way IF Statements.      Sixpak
                            *Deleted unused coding.                 Sixpak
VERS. 2017-1 (May   2017)   *Increased max. point to 600,000        Sixpak
                            *Updated based on user feedback         Sixpak
                                                                    Sixpak
OWNED, MAINTAINED AND DISTRIBUTED BY                                Sixpak
-----------------------------------                                 Sixpak
THE NUCLEAR DATA SECTION                                            Sixpak
INTERNATIONAL ATOMIC ENERGY AGENCY                                  Sixpak
P.O. BOX 100                                                        Sixpak
A-1400, VIENNA, AUSTRIA                                             Sixpak
EUROPE                                                              Sixpak
                                                                    Sixpak
ORIGINALLY WRITTEN BY                                               Sixpak
-------------------------------------                               Sixpak
Dermott E. Cullen                                                   Sixpak
                                                                    Sixpak
PRESENT CONTACT INFORMATION                                         Sixpak
---------------------------                                         Sixpak
Dermott E. Cullen                                                   Sixpak
1466 Hudson Way                                                     Sixpak
Livermore, CA 94550                                                 Sixpak
U.S.A.                                                              Sixpak
Telephone  925-443-1911                                             Sixpak
E. Mail    RedCullen1@Comcast.net                                   Sixpak
Website    RedCullen1.net/HOMEPAGE.NEW                              Sixpak
                                                                    Sixpak
COLLABORATION                                                       Sixpak
=================================================================== Sixpak
DEVELOPED IN COLLABORATION WITH,                                    Sixpak
                                                                    Sixpak
*THE NATIONAL NUCLEAR DATA CENTER, BROOKHAVEN NATIONAL LAB          Sixpak
                                                                    Sixpak
*THE NUCLEAR DATA SECTION, IAEA, VIENNA, AUSTRIA                    Sixpak
                                                                    Sixpak
*CENTRO TECNICO AEROSPACIAL, SAO JOSE DOS CAMPOS, BRAZIL           Sixpak
                                                                    Sixpak
AS A PART OF AN INTERNATIONAL PROJECT ON THE EXCHANGE OF            Sixpak
NUCLEAR DATA                                                        Sixpak
                                                                    Sixpak
ACKNOWLEDGEMENT (VERSION 92-1)                                      Sixpak
```

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======================================================================= Sixpak
THE AUTHOR THANKS SOL PEARLSTEIN (BROOKHAVEN NATIONAL LAB) FOR     Sixpak
SIGNIFICANTLY CONTRIBUTING TOWARD IMPROVING THE ACCURACY AND       Sixpak
COMPUTER INDEPENDENCE OF THIS CODE - THANKS, SOL                   Sixpak
                                                                   Sixpak
ACKNOWLEDGEMENT (VERSION 92-4)                                     Sixpak
======================================================================= Sixpak
THE AUTHOR THANKS BOB MACFARLANE (LOS ALAMOS) FOR SUGGESTING HOW   Sixpak
TO PROPERLY OUTPUT THE PHOTON PRODUCTION DATA TO PUT IT INTO        Sixpak
EXACTLY THE FORM NEEDED FOR USE IN PROCESSING CODES.               Sixpak
                                                                   Sixpak
THE AUTHOR THANKS CHRIS DEAN (WINFRITH) FOR POINTING OUT ERRORS    Sixpak
IN THE EARLIER TREATMENT OF THE KALBACH-MANN FORMALISM AND IN      Sixpak
THE DEFINITION OF THE ISOTROPIC ANGULAR DISTRIBUTION FLAG (LI).    Sixpak
                                                                   Sixpak
AUTHORS MESSAGE                                                    Sixpak
======================================================================= Sixpak
THE COMMENTS BELOW SHOULD BE CONSIDERED THE LATEST DOCUMENTATION   Sixpak
INCLUDING ALL RECENT IMPROVEMENTS. PLEASE READ ALL OF THESE        Sixpak
COMMENTS BEFORE IMPLEMENTING AND USING THESE CODES.                Sixpak
                                                                   Sixpak
AT THE PRESENT TIME WE ARE ATTEMPTING TO DEVELOP A SET OF COMPUTER Sixpak
INDEPENDENT PROGRAMS THAT CAN EASILY BE IMPLEMENTED ON ANY ONE     Sixpak
OF A WIDE VARIETY OF COMPUTERS. IN ORDER TO ASSIST IN THIS PROJECT Sixpak
IT WOULD BE APPECIATED IF YOU WOULD NOTIFY THE AUTHOR OF ANY       Sixpak
COMPILER DIAGNOSTICS, OPERATING PROBLEMS OR SUGGESTIONS ON HOW TO  Sixpak
IMPROVE THIS PROGRAM. HOPEFULLY, IN THIS WAY FUTURE VERSIONS OF    Sixpak
THIS PROGRAM WILL BE COMPLETELY COMPATIBLE FOR USE ON YOUR         Sixpak
COMPUTER.                                                          Sixpak
                                                                   Sixpak
PURPOSE                                                            Sixpak
======================================================================= Sixpak
1) CHECK ALL DOUBLE-DIFFERENTIAL DATA (MF=6)                       Sixpak
                                                                   Sixpak
2) OUTPUT EQUIVALENT MF = 4, 5, 12, 14 AND 15 DATA.                Sixpak
                                                                   Sixpak
DATA CHECKING                                                      Sixpak
======================================================================= Sixpak
ALL OF THE ENDF/B-VI MF=6 DATA IS CHECKED - FOR DETAILS SEE BELOW. Sixpak
                                                                   Sixpak
THE MF=6 DATA IS NOT CORRECTED AND OUTPUT IN THE ENDF/B FORMAT.    Sixpak
IT IS MERELY CHECKED. IF ERRORS ARE FOUND IT IS UP TO THE USER     Sixpak
TO TAKE CORRECTIVE ACTION ON THE MF=6 DATA.                        Sixpak
                                                                   Sixpak
IN CONTRAST WHEN PROBLEMS ARE FOUND IN DATA WHICH WILL BE OUTPUT   Sixpak
IN THE ENDF/B FORMAT (MF=4, 5, 12, 14 AND 15), WHENEVER POSSIBLE   Sixpak
CORRECTIVE ACTION WILL BE TAKEN.                                   Sixpak
                                                                   Sixpak
FURTHER CHECKS AND CORRECTIONS                                     Sixpak
======================================================================= Sixpak
ONCE THE DATA HAS BEEN OUTPUT IN MF = 4, 5, 12, 14 AND 15 FORMATS  Sixpak
FURTHER CORRECTIVE ACTION CAN BE TAKEN AS FOLLOWS,                 Sixpak
                                                                   Sixpak
PROGRAM LEGEND                                                     Sixpak
==============                                                     Sixpak
CAN BE USED TO CORRECT ANGULAR DISTRIBUTIONS WHICH ARE NEGATIVE,   Sixpak
TO CONVERT FROM LEGENDRE COEFFICIENTS TO TABULATED ANGULAR         Sixpak
DISTRIBUTIONS AND GENERALLY PERFORM MORE EXTENSIVE TESTS OF        Sixpak
ALL MF=4 DATA.                                                     Sixpak
                                                                   Sixpak
PROGRAM EVALPLOT                                                   Sixpak
================                                                   Sixpak
VERSION 92-1 AND LATER VERSIONS CAN PLOT ALL OF THE MF=4, 5 AND 15 Sixpak
```

DATA OUTPUT BY THIS CODE. EARLIER VERSIONS CAN PLOT MF=4 AND 5. GRAPHICS IS AN EXCELLENT WAY TO CHECK THIS DATA.

PROGRAM PLOTTAB

THIS IS A GENERAL PLOTTING PROGRAM AND THERE IS AN INTERFACE IN THIS CODE TO PRODUCE OUTPUT FOR ANY MF=6 DATA IN THE PLOTTAB INPUT FORMAT. THIS PROGRAM CAN BE USED TO CHECK ALL OF THE MF=6 DATA AS WELL AS THE EQUIVALENT MF=4, 5, 12, 14 AND 15 DATA - AS WELL AS COMPARING THE ORIGINAL MF=6 AND EQUIVALENT DATA.

DATA OUTPUT

THE ENDF/B MF=4, 5, 12, 14 AND 15 FORMATS ONLY ALLOW FOR NEUTRONS INCIDENTS

THE ENDF/B MF=4 AND 5 FORMATS ONLY ALLOW FOR NEUTRONS OUTGOING.

THE ENDF/B MF=12, 14 AND 15 ONLY ALLOWS FOR PHOTONS OUTGOING.

THESE ARE THE ONLY COMBINATIONS OF DATA OUTPUT BY THIS CODE.

ALL OTHER COMBINATIONS OF INCIDENT AND OUTGOING PARTICLES ARE CHECKED, BUT THE RESULTS CANNOT BE OUTPUT IN THE ENDF/B FORMAT. HOWEVER, USING THE PLOTTAB INTERFACE BUILT INTO THIS CODE THIS DATA CAN, AND HAS BEEN, OUTPUT AND CHECKED.

THE NEUTRON DATA IN MF=4 CAN BE IN THE FORM OF EITHER TABULATED ANGULAR DISTRIBUTIONS OR LEGENDRE COEFFICIENTS.

THE NEUTRON (MF=5) OR PHOTON (MF=15) SPECTRA ARE BOTH IN EXACTLY THE SAME FORMAT = ARBITRARY TABULATED FUNCTIONS - ENDF/B OPTION LF=1.

ENDF/B DATA OUTPUT ORDER

ENDF/B DATA IS OUTPUT IN ASCENDING MAT, MF, MT ORDER. IN ORDER TO ALLOW THIS PROGRAM TO PRODUCE ALL OUTPUT IN A SINGLE PASS THROUGH THE MF=6 DATA, OUTPUT FOR EACH (MAT, MT) IS OUTPUT TO SEPERATE FILES FOR MF=4, 5, 12, 14 AND 15.

FOR SUBSEQUENT USE THE ENDF/B FORMATTED DATA OUTPUT BY THIS CODE CAN BE MERGED TOGETHER USING PROGRAM MERGER (CONTAIN THE AUTHOR OF THIS CODE FOR A COPY OF MERGER), E.G., MERGE MF=12, 14 AND 15 DATA IN ORDER TO THEN CALCULATE PHOTON PRODUCTION DATA OR MF=4 AND 5 CAN BE MERGED TOGETHER TO CALCULATE NEUTRON TRANSFER - OR ALL OF THEM CAN BE MERGED TOGETHER TO PERFORM NEUTRON AND PHOTON CALCULATIONS.

CORRELATED (MF=6) VS. UNCORRELATED (MF=4 AND 5) DATA

THE ENDF/B DOUBLE DIFFERENTAL = CORRELATED - DATA IN MF=6 REPRESENTS DATA IN THE FORM,

$$F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F(E,EP,COS)$$

SIG(E) = MF=3 CROSS SECTIONS
Y(E) = YIELD (MULTIPLICITY)
G0(E,EP) = ENERGY SPECTRUM
F(E,EP,COS) = ANGULAR DISTRIBUTION

IN A SITUATION WHERE YOU HAVE MONOENERGETIC AND MONODIRECTIONAL NEUTRONS INCIDENT YOU WILL BE ABLE TO OBSERVE CORRELATION EFFECTS

IN THE NEUTRON SPECTRUM AND ANGULAR DISTRIBUTION.

EVEN IN SITUATIONS WHERE YOU HAVE A NARROW SPECTRUM OF NEUTRONS THAT ARE HIGHLY DIRECTIONALLY ORIENTED YOU MAY BE ABLE TO OBSERVE THESE CORRELATION EFFECTS, E.G., A NARROW 14 MEV FUSION SOURCE INCIDENT ON THE FIRST WALL OF A CTR DEVICE.

FOR SUCH SITUATIONS USE OF THE CORRELATED (MF=6) DATA IS REQUIRED IN CALCULATIONS.

HOWEVER, IN MANY APPLICATIONS WHERE THERE IS A BROAD SPECTRUM OF NEUTRONS AND THE NEUTRON FLUX IS NOT HIGHLY DIRECTIONALLY ORIENTED, THE NEUTRON MULTIPLICATION, SPECTRUM AND ORIENTATION CAN BE FAIRLY ACCURATELY CALCULATED WITHOUT CONSIDERING CORRELATION EFFECTS.

THE UNCORRELATED DATA PRODUCED BY THIS CODE REPLACES THE CORRELATED DATA,

$$F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F(E,EP,COS)$$

BY THE UNCORRELATED DATA,

$$F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F0(E,COS)$$

BY INTEGRATING G0(E,EP)*F(E,EP,COS) OVER SECONDARY ENERGY (EP) TO DEFINE AN AVERAGE ANGULAR DISTRIBUTION, F0(E,COS).

WHAT IS LOST IN THIS PROCESS IS THE CORRELATION BETWEEN EP AND COS SO THAT IN A TRANSPORT CALCULATION ALL MOMENTS OF THE FLUX WILL HAVE THE SAME SPECTRUM, G0(E,EP) AND EACH WILL BE EFFECTED BY THE AVERAGE ANGULAR DISTRIBUTION.

FOR APPLICATIONS TO HIGH ENERGY FUSION APPLICATIONS CORRELATED DATA SHOULD BE USED. HOWEVER, FOR LOWER ENERGY APPLICATIONS, SUCH AS FISSION REACTORS, IT SHOULD BE ADEQUATE TO USE THE UNCORRELATED DATA - IN THIS CASE THE MOST IMPORTANT EFFECT WILL BE THE OVERALL NEUTRON MULTIPLICATION AND SPECTRUM.

AN IMPORTANT CONSIDERATION IN DESIGNING THIS PROGRAM IS THAT MANY COMPUTER CODES - DATA PROCESSING AND TRANSPORT CODES - CANNOT USE THE CORRELATED (MF=6) DATA - NOR ARE THEY INTENDED FOR HIGH ENERGY USE. FOR THESE CODES THE UNCORRELATED DATA PRODUCED BY THIS CODE SHOULD BE ADEQUATE TO MEET THEIR NEEDS.

WARNING - IT CANNOT BE STRESSED ENOUGH THAT THE OUTPUT OF THIS CODE SHOULD ONLY BE USED FOR LOW ENERGY APPLICATIONS - FAILURE TO HEED THIS WARNING CAN LEAD TO COMPLETELY UNRELIABLE RESULTS.

ENDF/B FORMAT

THIS PROGRAM ONLY USES THE ENDF/B BCD OR CARD IMAGE FORMAT (AS OPPOSED TO THE BINARY FORMAT) AND CAN HANDLE DATA IN ANY VERSION OF THE ENDF/B FORMAT (I.E., ENDF/B-I, II,III, IV, V OR VI FORMAT).

IT IS ASSUMED THAT THE DATA IS CORRECTLY CODED IN THE ENDF/B FORMAT AND NO ERROR CHECKING IS PERFORMED. IN PARTICULAR IT IS ASSUMED THAT THE MAT, MF AND MT ON EACH LINE IS CORRECT. SEQUENCE NUMBERS (COLUMNS 76-80) ARE IGNORED ON INPUT, BUT WILL BE CORRECTLY OUTPUT ON ALL LINES. THE FORMAT OF SECTION MF=1, MT=451 AND ALL SECTIONS OF MF=6 MUST BE CORRECT. THE PROGRAM SKIPS ALL OTHER SECTIONS OF DATA AND AS SUCH IS INSENSITIVE TO THE FORMAT OF ALL OTHER SECTIONS.

CONTENTS OF OUTPUT

5 ENDF/B FORMATTED OUTPUT FILES ARE PRODUCED FOR NEUTRON INCIDENT DATA,

1) ENDFB.MF4 - ANGULAR DISTRIBUTIONS AND LEGENDRE COEFFICIENTS FOR NEUTRONS
2) ENDFB.MF5 - TABULATED NEUTRON ENERGY SPECTRA
3) ENDFB.M12 - PHOTON EMISSION MULTIPLICITY
4) ENDFB.M14 - PHOTON EMISSION ANGULAR DISTRIBUTIONS (ALWAYS ISOTROPIC)
5) ENDFB.M15 - TABULATED PHOTON EMISSION SPECTRA

EMITTED PARTICLE YIELD

NEUTRONS

IN MF=6 THE YIELD FOR EACH REACTION IS THE ACTUAL MULTIPLICITY OF THE REACTION, E.G., (N,2N) = 2. IN USING MF=4 AND 5 DATA THE ENDF/B CONVENTION IS THAT THE MULTIPLICITY IS IMPLIED BY THE MT NUMBER, E.G., MT=16 = (N,2N) = 2.

THE ONLY EXCEPT IN ENDF/B-VI IS MT=201 = TOTAL NEUTRON PRODUCTION WHERE AN ACTUAL ENERGY DEPENDENT YIELD IS INCLUDED IN MF=6. HOWEVER, IN THIS CASE THE MF=3 CROSS SECTION INCLUDES THE MULTIPLICITY (S. PEARLSTEIN, PRIVATE COMMUNICATION, JAN. 1992), SIG(MT=201) = 2*SIG(N,2N)+3*SIG(N,3N).....ETC.

SO THAT FOR ALL ENDF/B-VI DATA AS OF JANUARY 1992 THE MF=4 AND 5 DATA OUTPUT BY THIS CODE CAN BE USED IN CONJUNCTION WITH THE MF=3 CROSS SECTIONS - WITHOUT ANY REFERENCE TO THE MF=6 YIELD.

PHOTONS

UNLIKE THE NEUTRONS WHERE WITH ONLY ONE EXCEPTION (MT=201) THE MF=6 YIELD IS ENERGY INDEPENDENT, IN THE CASE OF PHOTON EMISSION ALMOST ALL OF THE PHOTONS HAVE AN ENERGY DEPENDENT YIELD.

THIS PROGRAM WILL OUTPUT THE PHOTON MULTIPLICITY IN MF=12 AND INDICATE THAT THERE IS A NORMALIZED DISTRIBUTION IN MF=15 (LF=1 IN MF=12).

THIS PROGRAM WILL OUTPUT THE NORMALIZED PHOTON SPECTRA IN MF=15. CONTINUOUS ENERGY SPECTRA AND DISCRETE PHOTONS WILL ALL BE OUTPUT AS NORMALIZED SPECTRA.

THIS PROGRAM WILL ALSO OUTPUT MF=14 PHOTON ANGULAR DISTRIBUTION DATA, ALWAYS USING THE ISOTROPIC FLAG TO MINIMIZE OUTPUT.

WARNING OF ENERGY DEPENDENT YIELD

THIS PROGRAM WILL PRINT A WARNING MESSAGE IF A SECTION OF DATA BEING OUTPUT IN THE ENDF/B FORMAT HAS AN ENERGY DEPENDENT MF=6 YIELD AND THE EMITTED PARTICLE IS A NEUTRON - SINCE THE ENDF/B CONVENTION IS THAT FOR EACH MT NUMBER THE MULTIPLICITY IS IMPLIED WE DO NOT EXPECT AN ENERGY DEPENDENT MULTIPLICITY FOR NEUTRON EMISSION.

USING THE OUTPUT

NOTE, THAT IN USING THIS DATA, STARTING FROM THE RELATIONSHIP,

F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F0(E,COS)

USING THE ENDF/B CONVENTION THAT THE MULTIPLICITY IS EITHER IMPLIED BY THE MT NUMBER (E.G., MT=16 = N,2N - MULTIPLICITY = 2) OR INCLUDED IN THE CROSS SECTION (E.G., MT=201 = TOTAL NEUTRON PRODUCTION) ALL THE INFORMATION REQUIRED FOR A CALCULATION IS AVAILABLE IN,

MF=3 - SIG(E)
MF=4 - F0(E,COS) - FOR OUTGOING NEUTRONS
MF=5 - G0(E,EP) - FOR OUTGOING NEUTRONS
MF=12 - Y(E) - FOR OUTGOING PHOTONS
MF=14 - F0(E,COS) - FOR OUTGOING PHOTONS (ALWAYS ISOTROPIC)
MF=15 - G0(E,EP) - FOR OUTGOING PHOTONS

DOCUMENTATION

ONLY SECTIONS OF MF=4, 5, 12, 14, 15 ARE OUTPUT ON A ENDF/B FILE. THE ONLY DOCUMENTATION IS THE ENDF/B TAPE LABEL (FIRST RECORD OF EACH FILE) WHICH IDENTIFIES THE DATA AS SIXPAK OUTPUT.

REACTION INDEX

THIS PROGRAM DOES NOT USE THE REACTION INDEX WHICH IS GIVEN IN SECTION MF=1, MT=451 OF EACH EVALUATION.

SECTION SIZE

ALL OF THE DATA IN ENDF/B-VI, MF=6 ARE QUITE SMALL TABLES. AS SUCH THIS PROGRAM ONLY ALLOWS TABLES OF UP TO 12000 POINTS (12,000 X, Y VALUES). THIS SIZE IS MORE THAN ADEQUATE TO HANDLE ALL OF THE CURRENT ENDF/B-VI DATA, AND IT CAN BE EASILY INCREASED TO HANDLE ANY NEWER DATA AS IT BECOMES AVAILABLE.

PLEASE CONTACT THE AUTHOR IF YOU HAVE AN EVALUATION WHICH EXCEEDS THIS LIMIT.

SELECTION OF DATA

THE PROGRAM SELECTS DATA TO BE PROCESSED BASED ON MAT/MT RANGES (MF=6 ASSUMED). THIS PROGRAM ALLOWS UP TO 100 MAT/MT RANGES TO BE SPECIFIED BY INPUT PARAMETERS. THE PROGRAM WILL ASSUME THAT THE ENDF/B TAPE IS IN MAT ORDER. THE PROGRAM WILL TERMINATE EXECUTION WHEN A MAT IS FOUND THAT IS ABOVE ALL REQUESTED MAT RANGES.

PROGRAM OPERATION

EACH SECTION (MT) OF MF=6 DATA IS SUBDIVIDED INTO SUBSECTIONS - ONE SUBSECTION FOR EACH EMITTED PARTICLE.

EACH SUBSECTION OF DATA IS CONSIDERED SEPARATELY. EACH SUBSECTION OF ENDF/B MF=6 DATA TO PROCESS IS IN THE FORM,

F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F(E,EP,COS)

SIG(E) = MF=3 CROSS SECTIONS
Y(E) = YIELD (MULTIPLICITY)
G0(E,EP) = ENERGY SPECTRUM
F(E,EP,COS) = ANGULAR DISTRIBUTION

G0(E,EP) = 1 WHEN INTEGRATED OVER EP (SECONDARY ENERGY)
G0(E,EP)*F(E,EP,COS) = 1 WHEN INTEGRATED OVER EP AND COS

```
THIS PROGRAM WILL DEFINE THE ZEROTH ORDER MOMENTS OF THE           Sixpak
ENERGY AND ANGULAR DISTRIBUTIONS,                                  Sixpak
                                                                   Sixpak
G0(E,EP)  = G0(E,EP)*F(E,EP,COS) INTEGRATED OVER COS               Sixpak
F0(E,COS) = G0(E,EP)*F(E,EP,COS) INTEGRATED OVER EP                Sixpak
                                                                   Sixpak
FOR NEUTRON INDUCED REACTIONS THE ENDF/B FORMATTED OUTPUT WILL BE  Sixpak
                                                                   Sixpak
F0(E,COS)- IN ENDFB.MF4 FOR NEUTRONS OUT OF A REACTION             Sixpak
G0(E,EP) - IN ENDFB.MF5 FOR NEUTRONS OUT OF A REACTION             Sixpak
         - IN ENDFB.M15 FOR PHOTONS OUT OF A REACTION              Sixpak
                                                                   Sixpak
FOR NEUTRONS INCIDENT AND NEUTRONS EMITTED THIS DATA WILL BE       Sixpak
OUTPUT IN MF=4 AND 5 FORMATS.                                      Sixpak
                                                                   Sixpak
FOR NEUTRONS INCIDENT AND PHOTONS EMITTED THIS DATA WILL BE        Sixpak
OUTPUT IN MF=15 FORMAT - THE SPECTRA ARE OUTPUT AND THE            Sixpak
ANGULAR DISTRIBUTION IS IGNORED.                                   Sixpak
                                                                   Sixpak
ALL PHOTON EMISSION IN THE ENDF/B-VI LIBRARY AS OF JANUARY 1992    Sixpak
IS ISOTROPIC AND AS SUCH NO DISTRIBUTION OF PHOTON ANGULAR         Sixpak
DISTRIBUTIONS NEED BE OUTPUT - IT IS ALWAYS ISOTROPIC.             Sixpak
                                                                   Sixpak
FOR ALL OTHER COMBINATIONS INCIDENT AND EMITTED PARTICLES          Sixpak
THERE WILL BE NO ENDF/B FORMATTED OUTPUT.                          Sixpak
                                                                   Sixpak
VARIATIONS FROM ENDF/B MANUAL                                      Sixpak
================================================================== Sixpak
LAW=1, LANG=2 = KALBACH-MANN                                       Sixpak
============================                                       Sixpak
FOR THE DISTRIBUTIONS,                                             Sixpak
                                                                   Sixpak
F(MU,E,EP) = G0(E,EP)*A*(COSH(MU*A)+R(E,EP)*SINH(MU*A))            Sixpak
                                                                   Sixpak
G0(E,EP) = 1 - WHEN INTEGRATED OVER EP.                            Sixpak
                                                                   Sixpak
A*(COSH(MU*A)+R(E,EP)*SINH(MU*A)) = 2 - WHEN INTEGRATD OVER MU     Sixpak
                                                                   Sixpak
THIS MEANS AS DEFINED IN THE ENDF/B MANUAL THE DISTRIBUTIONS       Sixpak
ARE NORMALIZED TO 2, INSTEAD OF 1. IN ORDER TO OBTAIN CORRECTLY    Sixpak
NORMALIZED DISTRIBUTIONS THE DISTRIBUTION SHOULD BE DEFINED        Sixpak
TO INCLUDE A FACTOR OF 1/2 MULTIPLYING THE ANGULAR PART OF         Sixpak
THE DISTRIBUTION.                                                  Sixpak
                                                                   Sixpak
F(MU,E,EP) = G0(E,EP)*0.5*A*(COSH(MU*A)+R(E,EP)*SINH(MU*A))        Sixpak
                                                                   Sixpak
THIS IS THE FORM USED IN THIS CODE                                 Sixpak
                                                                   Sixpak
LAW=1, ND NOT 0 = DISCRETE SECONDARY ENERGY DISTRIBUTION           Sixpak
=======================================================            Sixpak
THE ENDF/B MANUAL SAYS THESE ARE FLAGGED WITH NEGATIVE ENERGIES.   Sixpak
IN ENDF/B-VI ALL OF THESE HAVE POSITIVE ENERGY. THIS CODE DOES     Sixpak
NOT CONSIDER THE ENDF/B-VI DATA TO BE IN ERROR.                    Sixpak
                                                                   Sixpak
WITH THE CONVENTION ACTUALLY USED IN ENDF/B-VI ALL SECONDARY       Sixpak
ENERGIES SHOULD BE NON-NEGATIVE AND IN ASCENDING ENERGY ORDER      Sixpak
FOR EACH INCIDENT ENERGY.                                          Sixpak
                                                                   Sixpak
FROM THE ENDF/B MANUAL IT IS NOT OBVIOUS WHAT G0(E,EP) SHOULD BE   Sixpak
FOR DISCRETE PHOTONS - PHYSICALLY THIS IS A DELTA FUNCTION. IN     Sixpak
ENDF/B-VI IT IS ENTERED AS 1.0 = INTERPRETING IT AS INTEGRATED     Sixpak
OVER SECONDARY ENERGY - IN WHICH CASE THE DELTA FUNCTION = 1.0.    Sixpak
                                                                   Sixpak
```

LIMITATIONS Sixpak
========== Sixpak
CHECKING DATA Sixpak
========== Sixpak
THIS PROGRAM CHECKS ALL ENDF/B-VI MF=6 DATA. THE FOLLOWING CHECKS Sixpak
ARE PERFORMED. Sixpak
Sixpak
PARAMETERS Sixpak
========== Sixpak
ALL PARAMETERS ARE CHECKED FOR CONSISTENCY. IF PARAMETERS ARE Sixpak
NOT CONSISTENT THE PROGRAM MAY NOT BE ABLE TO PERFORM THE Sixpak
FOLLOWING TESTS AND WILL MERELY SKIP A SECTION OF DATA. Sixpak
Sixpak
INTERPOLATION LAWS Sixpak
================== Sixpak
ALL INTEGRATIONS ARE PERFORMED USING THE INTERPOLATION LAW GIVEN Sixpak
FOR SECONDARY ENERGY AND/OR COSINE. INTEGRATIONS ARE NOT Sixpak
PERFORMED OVER INCIDENT - ONLY INTEGRATION OVER SECONDARY ENERGY Sixpak
AND/OR COSINE ARE PERFORMED AT EACH INCIDENT ENERGY. THEREFORE Sixpak
THE INTERPOLATION LAW FOR INCIDENT ENERGY IS NOT USED BY THIS Sixpak
CODE. Sixpak
Sixpak
ALL INTERPOLATION LAWS ARE CHECKED. ALL DATA ASSOCIATED WITH Sixpak
INTERPOLATION LAWS ARE CHECKED, E.G., NO NON-NEGATIVE VALUES Sixpak
REQUIRING LOG INTERPOLATION. IN ORDER TO PERFORM REQUIRED Sixpak
INTEGRALS OVER COS AND EP IT IS IMPERATIVE THAT THE INTERPOLATION Sixpak
LAWS BE COMPATIBLE WITH THE DATA. Sixpak
Sixpak
ENDF/B-VI ALLOWS NEW INTERPOLATION LAWS FOR CORRESPONDING POINT Sixpak
AND UNIT BASE TRANSFORMATION INTERPOLATION. NONE OF THESE NEW Sixpak
INTERPOLATION LAWS ARE USED IN THE ENDF/B-VI LIBRARY AS OF Sixpak
JANUARY 1992 TO INTERPOLATE IN SECONDARY ENERGY OR COSINE. Sixpak
THEREFORE THIS PROGRAM CAN PERFORM ALL OF THE REQUIRED INTEGRALS Sixpak
OVER SECONDARY ENERGY AND/OR COSINE USING ONLY THE OLDER Sixpak
INTERPOLATION CODES. THIS PROGRAM ONLY PERFORMS INTEGRALS FOR Sixpak
EACH INCIDENT ENERGY, SO THAT INTERPOLATION IN INCIDENT ENERGY Sixpak
IS NOT PERFORMED BY THIS PROGRAM. Sixpak
Sixpak
NEW INTERPOLATION SCHEMES ARE USED FOR INCIDENT ENERGY - FOR Sixpak
EXAMPLE, CORRESPONDING POINT INTERPOLATION IS SPECIFIED TO ALLOW Sixpak
INTERPOLATION IN G0(E,EP) TO SIMULATE CASES WHERE THE INPUT ENERGY Sixpak
LIMIT IS DEFINED BY E-EP = A DIAGONAL CURVE ACROSS (E,EP) SPACE. Sixpak
THIS INTERPOLATION CODE CANNOT BE SPECIFIED IN THE MF=5 OUTPUT Sixpak
OF THIS CODE - MF=5 ONLY ALLOWS THE OLDER INTERPOLATION LAWS Sixpak
INT=1 THROUGH 5. THEREFORE THIS PROGRAM WILL USE THE CLOSEST Sixpak
CORRESPONDING INTERPOLATION CODE FOR OUTPUT TO MF=5. FOR USE Sixpak
WHERE THE OUTPUT OF THIS CODE = LOW ENERGY APPLICATIONS - THIS Sixpak
SHOULD HAVE LITTLE EFFECT ON RESULTS. Sixpak
Sixpak
FOR CONSISTENCY WITH EARLIER VERSIONS OF ENDF/B IN CREATING THE Sixpak
ENDF/B OUTPUT, IF ANY INPUT INTERPOLATION LAW IS NOT IN THE Sixpak
RANGE 1-5, IT WILL FIRST BE TESTED TO SEE IF MOD(10) IT IS Sixpak
IN THIS RANGE, FINALLY IF EVEN THIS DOESN'T WORK IT IS SET Sixpak
EQUAL TO 2 (LINEARLY INTERPOLATION). THIS METHOD WILL EFFECTIVELY Sixpak
REPLACE CORRESPONDING POINT AND UNIT BASE TRANSFORMATION BY THE Sixpak
CLOSEST RELATED INTERPOLATION LAW 1 THROUGH 5 - AGAIN NOTE, AS Sixpak
OF JANUARY 1992 NONE OF THESE NEW LAWS ARE USED IN ENDF/B-VI. IF Sixpak
THIS MUST BE DONE FOR INTERPOLATION IN SECONDARY ENERGY OR COSINE Sixpak
AN ERROR MESSAGE WILL BE PRINTED - SINCE THIS WOULD EFFECT THE Sixpak
ACCURACY OF THE INTEGRALS PERFORMED BY THIS PROGRAM. IF THIS MUST Sixpak
BE DONE FOR INCIDENT ENERGY NO MESSAGE IS PRINTED - SINCE THIS Sixpak
WILL NOT EFFECT THE ACCURACY OF THE INTEGRALS PERFORMED BY THIS Sixpak
PROGRAM. Sixpak

SPECTRA AND ANGULAR DISTRIBUTIONS
==========
ALL SPECTRA AND ANGULAR DISTRIBUTIONS ARE CHECKED TO INSURE THEY ARE NORMALIZED AND DO NOT INCLUDE ANY NEGATIVE VALUES.

LEGENDRE COEFFICIENTS
==========
THE NORMALIZATION, F0, CANNOT BE NEGATIVE.

LEGENDRE COEFFICIENTS IN NORMAL FORM ARE CHECKED TO INSURE THEY ARE IN THE RANGE -1 TO +1 = THE LEGENDRE EXPANSION OF A DELTA FUNCTION AT COS=+1 OR -1 - COEFFICIENTS SHOULD NOT EXCEED WHAT YOU GET FROM A DELTA FUNCTION.

ANGULAR DISTRIBUTIONS ARE CHECKED AT COS = -1, 0 AND +1.

CREATING ENDF/B OUTPUT
==========
THIS PROGRAM CAN CREATE EQUIVALENT MF =4, 5, 12, 14, 15 DATA FOR ALL OF THE DATA INCLUDED IN ENDF/B-VI AS OF JANUARY 1992, EXCEPT FOR 1 SECTION OF LAW=6 DATA (SEE DETAILS BELOW).

THIS PROGRAM HAS NOT BEEN TESTED ON OTHER DATA LIBRARIES, E.G., JEF, JENDL, ETC.

THE PROGRAM HAS THE FOLLOWING LIMITATION AS FAR AS CREATING ENDF/B FORMATTED OUTPUT.

ISOTROPIC PHOTON EMISSION
==========
FOR PHOTON EMISSION THE DISTRIBUTIONS ARE ASSUMED TO BE ISOTROPIC AND ONLY THE MULTIPLICITY IS OUTPUT IN MF=12, ISOTROPIC ANGULAR DISTRIBUTIONS IN MF=14 AND THE SPECTRA IN MF=15. ALL ENDF/B-VI MF=6 DATA AS OF JANUARY 1992 INCLUDE ONLY ISOTROPIC PHOTON EMISSION - SO THAT THIS IS NOT A LIMITATION ON TRANSLATING ENDF/B-VI DATA.

EITHER TABULATED OR LEGENDRE COEFFICIENTS
==========
FOR LAW=2 THE REPRESENTATION, EITHER TABULATED OR LEGENDRE COEFFICIENTS, CAN BE SPECIFIED FOR EACH INCIDENT ENERGY.

IN ORDER TO OBTAIN CORRECT ENDF/B OUTPUT THE REPRESENTATION MUST BE THE SAME FOR ALL INCIDENT ENERGIES = MF=4 DATA CAN ONLY BE TABULATED OR LEGENDRE OVER THE ENTIRE ENERGY RANGE.

YIELD AND OUTPUT NORMALIZATION
==========
THE YIELD INCLUDED WITH EACH SECTION OF DATA IS NOT USED FOR OUTPUT FOR NEUTRONS, BUT IS INCLUDED IN THE OUTPUT FOR PHOTONS. IN ALL CASES THE ANGULAR DISTRIBUTIONS AND SPECTRA OUTPUT ARE NORMALIZED TO UNITY.

LAW=0
=====
NO OUTPUT - INCIDENT NEUTRON - EMITTED PHOTON OR NEUTRON REACTIONS ARE NOT EXPECTED.

LAW=1
=====
FOR EACH INCIDENT ENERGY DISCRETE AND CONTINUOUS EMISSION SPECTRA CANNOT BE MIXED TOGETHER - THEY MUST BE ALL EITHER DISCRETE OR

```
CONTINUOUS. IF DISCRETE EMISSION IS GIVEN ONLY 1 SECONDARY         Sixpak
ENERGY (NEP=1) MAY BE GIVEN = A NORMALIZED DISTRIBUTION FOR A      Sixpak
SINGLE DISCRETE EMISSION ENERGY. ALL OF THE ENDF/B-VI DATA AS      Sixpak
OF JANUARY 1992 CONFORM TO THESE LIMITATIONS.                      Sixpak
                                                                   Sixpak
SINCE THE FLAG NA, TO INDICATE ISOTROPIC DISTRIBUTIONS, IS ONLY    Sixpak
GIVEN FOR EACH SECONDARY ENERGY (EP) THE PROGRAM CANNOT DECIDE     Sixpak
IN ADVANCE WHETHER OR NOT THE DISTRIBUTION WILL BE ISOTROPIC       Sixpak
AT ALL INCIDENT ENERGIES. THEREFORE ISOTROPIC DISTRIBUTIONS        Sixpak
WILL BE OUTPUT EITHER: LANG = 1 - AS 1 LEGENDRE COEFFICIENT = 0.0  Sixpak
OR LANG = NOT 1 - AS A 2 POINT ANGULAR DISTRIBUTION AT COS = -1.0  Sixpak
AND +1.0 WITH BOTH VALUES EQUAL TO 0.5 (A NORMALIZED ISOTROPIC     Sixpak
DISTRIBUTION).                                                     Sixpak
                                                                   Sixpak
DISCRETE PHOTONS ARE OUTPUT IN MF=15 AS 3 POINT DISTRIBUTIONS      Sixpak
WITH SECONDARY ENERGY POINTS AT EP-DEP, EP, EP+DEP, WHERE          Sixpak
DEP=0.001*EP. THE VALUES AT EP-DEP AND EP+DEP ARE 0.0, AND         Sixpak
AT EP THE VALUE IS 1000.0/EP TO NORMALIZE THE DISTRIBUTION.        Sixpak
                                                                   Sixpak
LAW=2                                                              Sixpak
=====                                                              Sixpak
NO LIMITATION ON REPRESENTATIONS.                                  Sixpak
                                                                   Sixpak
LAW=3                                                              Sixpak
=====                                                              Sixpak
NO LIMITATION ON REPRESENTATIONS.                                  Sixpak
                                                                   Sixpak
LAW=4                                                              Sixpak
=====                                                              Sixpak
NO OUTPUT - INCIDENT NEUTRON - EMITTED PHOTON OR NEUTRON           Sixpak
            REACTIONS ARE NOT EXPECTED.                            Sixpak
                                                                   Sixpak
LAW=5                                                              Sixpak
=====                                                              Sixpak
NO OUTPUT - INCIDENT NEUTRON - EMITTED PHOTON OR NEUTRON           Sixpak
            REACTIONS ARE NOT EXPECTED.                            Sixpak
                                                                   Sixpak
LAW=6                                                              Sixpak
=====                                                              Sixpak
NO OUTPUT - ENDF/B-VI ONLY INCLUDES 1 SECTION OF THIS TYPE OF DATA Sixpak
            FOR (N,D) 2N,P.                                        Sixpak
                                                                   Sixpak
LAW=7                                                              Sixpak
=====                                                              Sixpak
FOR EACH INCIDENT ENERGY THE REPRESENTATION MUST BE EITHER,        Sixpak
                                                                   Sixpak
1) SQUARE = FOR EACH INCIDENT COSINE EXACTLY THE SAME SECONDARY    Sixpak
            ENERGIES.                                              Sixpak
                                                                   Sixpak
2) LINEAR = FOR EACH INCIDENT COSINE THE INTERPOLATION LAW         Sixpak
            BETWEEN SECONDARY ENERGIES MUST BE LINEAR.             Sixpak
                                                                   Sixpak
THESE 2 PRESENTATIONS ARE THE ONLY ONES PRESENTED IN ENDF/B-VI     Sixpak
AS OF JANUARY 1992 - SO THIS PROGRAM CAN TRANSLATED ALL LAW=7      Sixpak
DATA FOR ENDF/B-VI.                                                Sixpak
                                                                   Sixpak
LABORATORY VS. CENTER-OF-MASS SYSTEM                               Sixpak
================================================================== Sixpak
IN MANY CASES PEOPLE ASSUME THAT FOR HEAVY (HIGH ATOMIC WEIGHT)    Sixpak
MATERIALS THE CENTER-OF-MASS AND LAB SYSTEMS ARE ALMOST IDENTICAL, Sixpak
SINCE IN THIS CASE THE CENTER-OF-MASS ENERGY WILL BE MUCH SMALLER  Sixpak
THAN THE INCIDENT ENERGY. FOR A PROCESS SUCH AS ELASTIC SCATTERING Sixpak
WHERE FOR HEAVY MATERIALS THE SECONDARY ENERGY, EP, WILL ALWAYS    Sixpak
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BE A LARGE FRACTION OF THE INCIDENT ENERGY, THIS ASSUMPTION IS     Sixpak
VALID. HOWEVER, FOR THE TYPICAL REACTIONS INCLUDED IN MF=6 THIS    Sixpak
IS NOT ALWAYS TRUE - IN MANY OF THESE CASES THE SECONDARY ENERGY   Sixpak
CAN EXTEND ALL THE WAY DOWN TO ZERO, AND IN PARTICULAR IT CAN      Sixpak
BE SMALL COMPARED TO THE CENTER-OF-MASS ENERGY - WHICH MAKES THE   Sixpak
TRANSFORMATION FROM CENTER-OF-MASS TO LAB IMPORTANT. THEREFORE     Sixpak
GENERALLY TO TREAT MF=6 DATA WE MUST CONSIDER THIS TRANSFORMATION. Sixpak
                                                                   Sixpak
THE FOLLOWING DISCUSSING ONLY APPLIES TO SPECTRA THAT MAY BE       Sixpak
OUTPUT IN MF=5 = ONLY DATA FOR NEUTRONS INCIDENT AND EMITTED -     Sixpak
IN PARTICULAR THE FOLLOWING DEFINITIONS ARE NOT GENERAL - THEY     Sixpak
ARE ONLY VALID FOR INCIDENT AND EMITTED NEUTRONS.                  Sixpak
                                                                   Sixpak
DOUBLE DIFFERENTIAL DATA IN MF=6 MAY BE GIVEN IN EITHER THE LAB    Sixpak
OR C.M. SYSTEM. SIMILARLY ANGULAR DISTRIBUTIONS IN MF=4 MAY BE     Sixpak
GIVEN IN EITHER THE LAB OR C.M. SYSTEM. IN CONTRAST ENERGY         Sixpak
SPECTRA IN MF=5 CAN ONLY BE GIVEN IN THE LABORATORY SYSTEM.        Sixpak
                                                                   Sixpak
THE ANGULAR DISTRIBUTIONS OUTPUT BY THIS CODE IN MF=4 ARE IN THE   Sixpak
SAME SYSTEM IN WHICH THEY ARE GIVEN IN MF=6 - EITHER LAB OR        Sixpak
CENTER-OF-MASS SYSTEM.                                             Sixpak
                                                                   Sixpak
THE ENERGY SPECTRA OUTPUT BY THIS CODE IN MF=5 MUST BE IN THE LAB  Sixpak
SYSTEM - THIS IS THE ONLY ALLOWED FORM FOR MF=5 DATA.              Sixpak
                                                                   Sixpak
FOR MF=6 SPECTRA GIVEN IN THE LAB SYSTEM THIS MERELY REQUIRES      Sixpak
COPYING THE GIVEN SPECTRA TO MF=5 OUTPUT.                          Sixpak
                                                                   Sixpak
FOR MF=6 SPECTRA GIVEN IN THE CENTER-OF-MASS SYSTEM ONLY FIRST     Sixpak
ORDER CORRECTIONS IN THE SPECTRA AND USED AND THEY ARE THEN        Sixpak
OUTPUT IN MF=5 AS IN THE LAB SYSTEM - THE FIRST ORDER CORRECTIONS  Sixpak
ARE DESCRIBED BELOW.                                               Sixpak
                                                                   Sixpak
DEFINING,                                                          Sixpak
MM      = CENTER OF MASS MOTION                                    Sixpak
CM      = OUTGOING (EMITTED) PARTICLE IN CENTER OF MASS            Sixpak
LAB     = OUTGOING (EMITTED) PARTICLE IN LAB                       Sixpak
THETA   = CM SCATTERING ANGLE RELATIVE TO INCIDENT DIRECTION       Sixpak
COS(CM) = COSINE OF THE CM SCATTERING ANGLE                        Sixpak
                                                                   Sixpak
FOR NEUTRONS INCIDENT WITH AN ENERGY, E, AND THEREFORE A SPEED,    Sixpak
                                                                   Sixpak
VN(E) = 2*SQRT(E)/MASS(IN)                                         Sixpak
                                                                   Sixpak
THE CENTER-OF-MASS SPEED IS GIVEN BY,                              Sixpak
                                                                   Sixpak
V(MM) = VN(E)/(1 + A)                                              Sixpak
                                                                   Sixpak
AND THE CENTER OF MASS ENERGY BY,                                  Sixpak
                                                                   Sixpak
E(MM) = 1/2*MASS(IN)*V(MM)**2                                      Sixpak
      = 1/2*MASS(IN)*VN(E)**2/(1 + A)**2                           Sixpak
      = E/(1 + A)**2                                               Sixpak
                                                                   Sixpak
FOR DISTRIBUTIONS GIVEN IN MF=6 IN THE CM, THE SPEED, V(CM),       Sixpak
SHOULD BE VECTORIALLY ADDED TO THAT OF OUTGOING PARTICLES TO       Sixpak
DEFINE THE OUTGOING PARTICLES LAB VELOCITY, AND IN TURN IT'S       Sixpak
ENERGY,                                                            Sixpak
                                                                   Sixpak
V(LAB)*COS(LAB) = V(MM) + V(CM)*COS(CM)                            Sixpak
V(LAB)*SIN(LAB) =         V(CM)*SIN(CM)                            Sixpak
                                                                   Sixpak
V(LAB)**2 = V(MM)**2 + V(CM)**2 + 2*COS(CM)*V(MM)*V(CM)            Sixpak
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                                                                      Sixpak
EP(LAB)    = 0.5*MASS(OUT)*V(LAB)**2                                  Sixpak
                                                                      Sixpak
           = E(MM) + EP(CM) + 2*COS(CM)*SQRT(E(MM)*EP(CM))            Sixpak
                                                                      Sixpak
WE CAN ALSO DEFINE THE REVERSE TRANSFORMATION USING,                  Sixpak
                                                                      Sixpak
V(CM)*COS(CM) = V(LAB)*COS(LAB) - V(MM)                               Sixpak
V(CM)*SIN(CM) = V(LAB)*SIN(LAB)                                       Sixpak
                                                                      Sixpak
V(CM)**2 = V(MM)**2 + V(LAB)**2 - 2*COS(LAB)*V(MM)*V(LAB)             Sixpak
                                                                      Sixpak
EP(CM)    = 0.5*MASS(OUT)*V(CM)**2                                    Sixpak
                                                                      Sixpak
           = E(MM) + EP(LAB) - 2*COS(LAB)*SQRT(E(MM)*EP(LAB))         Sixpak
                                                                      Sixpak
WE CAN DEFINE COS(LAB) FROM THE RELATIONSHIP,                         Sixpak
                                                                      Sixpak
V(LAB)*COS(LAB) = V(MM) + V(CM)*COS(CM)                               Sixpak
                                                                      Sixpak
COS(LAB)         =[V(MM) + V(CM)*COS(CM)]/V(LAB)                      Sixpak
                                                                      Sixpak
                  [V(MM) + V(CM)*COS(CM)]                             Sixpak
COS(LAB)         =-----------------------------------------           Sixpak
                  SQRT[V(MM)**2+V(CM)**2+2*COS(CM)*V(MM)*V(CM)]       Sixpak
                                                                      Sixpak
OR COS(CM) FROM THE RELATIONSHIP,                                     Sixpak
                                                                      Sixpak
V(CM)*COS(CM)  = V(LAB)*COS(LAB) - V(MM)                              Sixpak
                                                                      Sixpak
COS(CM)          =[V(LAB)*COS(LAB) - V(MM)]/V(CM)                     Sixpak
                                                                      Sixpak
                  [V(LAB)*COS(LAB) - V(MM)]                           Sixpak
COS(CM)          =-------------------------------------------------   Sixpak
                  SQRT[V(LAB)**2+V(CM)**2-2*COS(LAB)*V(LAB)*V(MM)]    Sixpak
                                                                      Sixpak
THE JACOBIAN CAN BE DEFINED FROM,                                     Sixpak
                                                                      Sixpak
V(LAB)*COS(LAB) = V(MM) + V(CM)*COS(CM)                               Sixpak
                                                                      Sixpak
J = D[COS(CM)]/D[COS(LAB)] = V(LAB)/V(CM)                             Sixpak
                           = SQRT[EP(LAB)/EP(CM)]                     Sixpak
                                                                      Sixpak
WITH THESE DEFINITIONS OF EP(LAB) AND COS(LAB) IN TERMS OF E(MM),     Sixpak
EP(CM) AND COS(CM) IT IS POSSIBLE TO PERFORM A POINT-BY-POINT         Sixpak
TRANSFORMATION OF DISTRIBUTIONS FROM THE CM TO LAB SYSTEM USING       Sixpak
THESE DEFINITIONS - OR IF WE WISHED WE COULD PERFORM THE REVERSE      Sixpak
TRANSFORMATION USING THE ABOVE RELATIONSHIPS AND THE IDENTITY,        Sixpak
                                                                      Sixpak
F(E,EP(LAB),COS(LAB))*D(COS(LAB))=F(E,EP(CM),COS(CM))*D(COS(CM))      Sixpak
                                                                      Sixpak
THIS IS NOT WHAT WILL BE DONE HERE, SINCE WE WILL ONLY BE             Sixpak
INTERESTED IN THE ZEROTH ORDER MOMENTS OF THESE DISTRIBUTIONS,        Sixpak
BUT WE WILL BE INTERESTED IN DEFINING THOSE MOMENTS IN THE            Sixpak
LAB SYSTEM IN TERMS OF MF=6 SPECTRA GIVEN IN THE CM SYSTEM USING,     Sixpak
                                                                      Sixpak
F(E,EP(LAB),COS(LAB)) = F(E,EP(CM),COS(CM))*J                         Sixpak
                                                                      Sixpak
THE LIMITS OF EP(LAB) ARE DEFINED BY SETTING COS(CM) = +1 OR -1,      Sixpak
                                                                      Sixpak
EP(LAB)    = (SQRT(EP(CM)) + SQRT(E(MM)))**2  FOR COS(CM) = +1        Sixpak
           = (SQRT(EP(CM)) - SQRT(E(MM)))**2  FOR COS(CM) = -1        Sixpak
                                                                      Sixpak
```

IN THIS FORM WE CAN SEE THAT AS LONG AS THE SECONDARY ENERGY IN THE CENTER-OF-MASS SYSTEM, EP(CM), IS MUCH LARGER THAN THE ENERGY OF THE CENTER-OF-MASS, E(MM), THE CENTER-OF-MASS AND LAB ENERGIES WILL BE ALMOST EQUAL - SIMILARLY FOR THE COSINE, IN THIS CASE COS(LAB) AND COS(CM) WILL BE ALMOST EQUAL - HOWEVER, FOR THE MF=6 DATA WE CANNOT ASSUME THAT THIS IS TRUE. Sixpak

TO FIRST ORDER THE ANGULAR DEPENDENCE CAN BE IGNORED, Sixpak

EP(LAB) = E(MM) + EP(CM) Sixpak

ALL THIS SAYS IS THAT TO FIRST ORDER THE EFFECT OF TRANSFORMING FROM THE CM TO LAB SYSTEM IS TO INCREASE THE ENERGY OF THE EMITTED PARTICLE IN THE CENTER-OF-MASS SYSTEM BY THE ENERGY OF THE CENTER-OF-MASS TO DEFINE THE LAB ENERGY. Sixpak

NOT ONLY THE ENERGY, BUT ALSO THE SPECTRA MUST BE TRANSFORMED. STARTING FROM THE DOUBLE DIFFERENTIAL DATA IN THE LAB SYSTEM, F(E,EP,COS(LAB)), WE CAN DEFINE THE LAB SCALAR SPECTRUM AS, Sixpak

G0(E,EP) = INTEGRAL F(E,EP,COS(LAB))*D(COS(LAB)) Sixpak

THIS IS THE NORMAL CALCULATION DEFINED ABOVE AND USED FOR DATA GIVEN IN THE LAB SYSTEM. Sixpak

STARTING FROM DATA IN THE CENTER OF MASS SYSTEM F(E,EP,COS(CM)), WE CAN USE THE RELATIONSHIP, Sixpak

F(E,EP,COS(LAB))*D(COS(LAB)) = F(E,EP,COS(CM))*J*D(COS(LAB)) Sixpak

J = SQRT(EP(LAB)/EP(CM)) - THE JACOBIAN Sixpak

= E(MM)/EP(CM) + 1 + 2*COS(CM)*SQRT(E(MM)/EP(CM)) Sixpak

AS IN THE CASE OF THE ENERGY, IN THIS FORM WE CAN SEE THAT AS LONG AS THE SECONDARY ENERGY IN THE CENTER-OF-MASS SYSTEM, EP(CM), IS LARGE COMPARED TO THE CENTER-OF-MASS ENERGY, E(MM), THE JACOBIAN IS ESSENTIALLY UNITY AND THE CENTER-OF-MASS AND LAB SPECTRA WILL BE VERY SIMILAR - AGAIN, GENERALLY WE CANNOT ASSUME THAT THIS IS TRUE FOR THE MF=6 SPECTRA. Sixpak

THEREFORE WE CAN ALSO DEFINE THE LAB SCALAR SPECTRUM IN TERMS OF THE CM SPECTRUM IN THE FORM, Sixpak

G0(E,EP) = INTEGRAL F(E,EP,COS(CM))*J*D(COS(LAB)) Sixpak

CONSISTENT WITH THE ABOVE ASSUMPTION THAT THE ANGULAR DEPENDENCE OF EP(LAB) CAN BE IGNORED THE JACOBIAN WILL NOT BE USED IN PERFORMING THESE INTEGRALS - IN WHICH CASE THE INTEGRAL REDUCES TO EXACTLY THE SAME FORM AS IF THE DATA WERE IN THE LAB SYSTEM. Sixpak

IT SHOULD BE NOTED THAT SINCE IN THIS CASE THE MF=4 ANGULAR DISTRIBUTIONS ARE GIVEN IN THE CM SYSTEM AND WHEN USED IN ANY APPLICATION THEY WILL BE TRANSFORMED TO THE LAB SYSTEM - WHEN THIS IS DONE THE JACOBIAN WILL BE APPLIED. Sixpak

IN THIS CODE WHERE WE ARE MOSTLY CONCERNED WITH CONSERVING THE NUMBER OF EMITTED PARTICLES AND AVERAGE ENERGIES THE NEUTRON SPECTRA OUTPUT IN MF=5 WILL NOT BE COMPLETELY CONVERTED TO THE LAB SYSTEM - ONLY FIRST ORDER CORRECTIONS WILL BE INCLUDED BY INCREASING THE EMITTED PARTICLE ENERGY BY THE CENTER OF MASS ENERGY, I.E., FOR A CENTER OF MASS SPECTRUM TABULATED AT CENTER OF MASS ENERGIES EP(CM) THESE WILL ALL BE UNIFORMLY INCREASED Sixpak

```
BY E(MM) TO ACCOUNT FOR THE CENTER OF MASS MOTION - THE SPECTRA    Sixpak
WILL NOT BE MODIFIED BY THE JACOBIAN FACTOR SQRT(EP(LAB)/EP(CM))   Sixpak
SINCE THIS WOULD REQUIRE A DETAILED TRANSFORMATION IN ENERGY AND   Sixpak
COS(THETA) SPACE - WHICH IS JUDGED NOT TO BE WORTH PERFORMING      Sixpak
WITHIN THE LIMITS OF WHERE THE OUTPUT FROM THIS CODE IS INTENDED   Sixpak
TO BE USED.                                                        Sixpak
                                                                   Sixpak
SINCE THE ANGULAR DISTRIBUTION IS ALWAYS OUTPUT IN THE SAME        Sixpak
SYSTEM AS WHICH IT IS GIVEN IN MF=6, NO TRANSFORMATION IS          Sixpak
REQUIRED FOR THE MF=4 OUTPUT.                                      Sixpak
                                                                   Sixpak
WHEN USED IN LOW ENERGY APPLICATIONS (E.G., FISSION REACTORS) THE  Sixpak
HIGH ENERGY SPECTRA PRESENTED IN MF=6 WILL BE MOSTLY IMPORTANT     Sixpak
SIMPLY IN CONSERVING PARTICLES, (E.G., AS IN (N,2N)) AND ENERGY    Sixpak
AND THE DETAILS OF THE CORRELATION AND GROSS ENERGY SPECTRA WILL   Sixpak
NOTE PLAY THAT IMPORTANT A ROLE. IN THIS CASE THE SPECTRA OUTPUT   Sixpak
BY THIS PROGRAM IN MF=5 SHOULD BE ADEQUATE.                        Sixpak
                                                                   Sixpak
PLOTTAB FORMATTED OUTPUT                                           Sixpak
================================================================== Sixpak
THIS PROGRAM CONTAINS ROUTINES TO PRODUCE OUTPUT THAT CAN BE USED  Sixpak
AS INPUT TO THE PLOTTAB CODE TO OBTAIN GRAPHIC RESULTS.            Sixpak
                                                                   Sixpak
THESE ROUTINES ARE DESIGNED ONLY FOR USE BY THE AUTHOR TO CHECK    Sixpak
THIS CODE. USERS ARE ASKED NOT TO ACTIVATE OR TRY TO USE THESE     Sixpak
ROUTINES. UNLESS YOU COMPLETELY UNDERSTAND THIS CODE THE RESULTS   Sixpak
CAN BE UNRELIABLE IF YOU ACTIVATE THESE ROUTINES.                  Sixpak
                                                                   Sixpak
INPUT FILES                                                        Sixpak
================================================================== Sixpak
UNIT  DESCRIPTION                                                  Sixpak
----  -----------                                                  Sixpak
   2  INPUT LINES (BCD - 80 CHARACTERS/RECORD)                     Sixpak
  10  ORIGINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)            Sixpak
                                                                   Sixpak
OUTPUT FILES                                                       Sixpak
================================================================== Sixpak
UNIT  DESCRIPTION                                                  Sixpak
----  -----------                                                  Sixpak
   3  OUTPUT REPORT (BCD - 120 CHARACTERS/RECORD)                  Sixpak
  11  ENDF/B DATA MF=4 (BCD - 80 CHARACTERS/RECORD)                Sixpak
  12  ENDF/B DATA MF=5 (BCD - 80 CHARACTERS/RECORD)                Sixpak
  14  ENDF/B DATA MF=15 (BCD - 80 CHARACTERS/RECORD)               Sixpak
  17  ENDF/B DATA MF=12 (BCD - 80 CHARACTERS/RECORD)               Sixpak
  18  ENDF/B DATA MF=14 (BCD - 80 CHARACTERS/RECORD)               Sixpak
  15  PLOTTAB INPUT PARAMETERS (BCD - 80 CHARACTERS/RECORD)        Sixpak
  16  PLOTTAB FORMATTED OUTPUT (BCD - 80 CHARACTERS/RECORD)        Sixpak
                                                                   Sixpak
SCRATCH FILES                                                      Sixpak
================================================================== Sixpak
NONE                                                               Sixpak
                                                                   Sixpak
OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILIO1 AND FILIO2)    Sixpak
================================================================== Sixpak
UNIT  FILE NAME                                                    Sixpak
----  ----------                                                   Sixpak
  2   SIXPAK.INP                                                   Sixpak
  3   SIXPAK.LST                                                   Sixpak
 10   ENDFB.IN                                                     Sixpak
 11   ENDFB.MF4                                                    Sixpak
 12   ENDFB.MF5                                                    Sixpak
 14   ENDFB.M15                                                    Sixpak
 17   ENDFB.M12                                                    Sixpak
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 18   ENDFB.M14                                                      Sixpak
 15   PLOTTAB.INP                                                    Sixpak
 16   PLOTTAB.CUR                                                    Sixpak
                                                                     Sixpak
                                                                     Sixpak
INPUT PARAMETERS                                                    Sixpak
=================================================================== Sixpak
LINE  COLS.  DESCRIPTION                                            Sixpak
----  -----  -----------                                            Sixpak
   1   1-72  ENDF/B INPUT DATA FILENAME                             Sixpak
             (STANDARD OPTION = ENDFB.IN)                           Sixpak
 2-N   1-6   MINIMUM MAT FOR REQUESTED RANGE                        Sixpak
       9-11  MINIMUM MT FOR REQUESTED RANGE                         Sixpak
      12-17  MAXIMUM MAT FOR REQUESTED RANGE                        Sixpak
      20-22  MAXIMUM MT FOR REQUESTED RANGE                         Sixpak
                                                                    Sixpak
LEAVE THE DEFINITION OF THE FILENAME BLANK - THE PROGRAM WILL       Sixpak
THEN USE THE STANDARD FILENAME (ENDFB.IN).                          Sixpak
                                                                    Sixpak
UP TO 100 MAT/MT RANGES MAY BE SPECIFIED. THE LIST OF RANGES IS     Sixpak
TERMINATED BY A BLANK LINE. IF THE FIRST INPUT LINE IS COMPLETELY   Sixpak
BLANK ALL DATA WILL BE PROCESSED.                                   Sixpak
                                                                    Sixpak
EXAMPLE INPUT NO. 1                                                 Sixpak
-------------------                                                 Sixpak
PROCESS ALL MF=6 DATA ON AN ENDF/B TAPE. USE THE STANDARD INPUT     Sixpak
DATA FILENAME ENDFB.IN IN THIS CASE THE USER CAN EITHER EXPLICITLY  Sixpak
SPECIFY THE FILENAME AND MAT/MT RANGE BY THE FOLLOWING  2 INPUT     Sixpak
LINES,                                                              Sixpak
                                                                    Sixpak
ENDFB.IN                                                            Sixpak
     1    1  9999  999                                             Sixpak
                        (BLANK LINE, TERMINATES REQUEST LIST)       Sixpak
                                                                    Sixpak
OR BY INPUTTING 2 BLANK LINE = PROCESS EVERYTHING.                  Sixpak
                                                                    Sixpak
EXAMPLE INPUT NO. 2                                                 Sixpak
-------------------                                                 Sixpak
PROCESS BE-9, MAT=425, MT=16. READ THE DATA FROM ENDFB6\BE9.        Sixpak
IN THIS CASE THE FOLLOWING 3 INPUT LINES ARE REQUIRED,              Sixpak
                                                                    Sixpak
ENDFBB6\BE9                                                         Sixpak
   425   16   425   16                                             Sixpak
                        (BLANK LINE, TERMINATES REQUEST LIST)       Sixpak
                                                                    Sixpak
EXAMPLE INPUT NO. 3                                                 Sixpak
-------------------                                                 Sixpak
PROCESS ALL MT=16 (N,2N) DATA. THIS CAN BE DONE BY SPECIFYING THE   Sixpak
MAXIMUM MAT RANGE = 1 TO 9999, AND MT=16 FOR THE MINIMUM AND        Sixpak
MAXIMUM MT RANGE. READ THE DATA FROM ENDFB6\K300. IN THIS CASE      Sixpak
CASE THE FOLLOWING 3 INPUT LINES ARE REQUIRED,                      Sixpak
                                                                    Sixpak
ENDFB6\K300                                                         Sixpak
     1   16  9999   16                                             Sixpak
                        (BLANK LINE, TERMINATES REQUEST LIST)       Sixpak
                                                                    Sixpak
=================================================================== Sixpak
```