```
========================================================================= 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
     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
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                            *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
                                                                     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    http://home.comcast.net/~redcullen1                       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
==================================================================== 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
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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. Sixpak
GRAPHICS IS AN EXCELLENT WAY TO CHECK THIS DATA. Sixpak
Sixpak
PROGRAM PLOTTAB Sixpak
=============== Sixpak
THIS IS A GENERAL PLOTTING PROGRAM AND THERE IS AN INTERFACE IN Sixpak
THIS CODE TO PRODUCE OUTPUT FOR ANY MF=6 DATA IN THE PLOTTAB Sixpak
INPUT FORMAT. THIS PROGRAM CAN BE USED TO CHECK ALL OF THE MF=6 Sixpak
DATA AS WELL AS THE EQUIVALENT MF=4, 5, 12, 14 AND 15 DATA - AS Sixpak
WELL AS COMPARING THE ORIGINAL MF=6 AND EQUIVALENT DATA. Sixpak
Sixpak
DATA OUTPUT Sixpak
== Sixpak
THE ENDF/B MF=4, 5, 12, 14 AND 15 FORMATS ONLY ALLOW FOR NEUTRONS Sixpak
INCIDENTS Sixpak
Sixpak
THE ENDF/B MF=4 AND 5 FORMATS ONLY ALLOW FOR NEUTRONS OUTGOING. Sixpak
Sixpak
THE ENDF/B MF=12, 14 AND 15 ONLY ALLOWS FOR PHOTONS OUTGOING. Sixpak
Sixpak
THESE ARE THE ONLY COMBINATIONS OF DATA OUTPUT BY THIS CODE. Sixpak
Sixpak
ALL OTHER COMBINATIONS OF INCIDENT AND OUTGOING PARTICLES ARE Sixpak
CHECKED, BUT THE RESULTS CANNOT BE OUTPUT IN THE ENDF/B FORMAT. Sixpak
HOWEVER, USING THE PLOTTAB INTERFACE BUILT INTO THIS CODE THIS Sixpak
DATA CAN, AND HAS BEEN, OUTPUT AND CHECKED. Sixpak

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 ENERGY AND ANGULAR DISTRIBUTIONS,

G0(E,EP) = G0(E,EP)*F(E,EP,COS) INTEGRATED OVER COS
F0(E,COS) = G0(E,EP)*F(E,EP,COS) INTEGRATED OVER EP

FOR NEUTRON INDUCED REACTIONS THE ENDF/B FORMATTED OUTPUT WILL BE

F0(E,COS)- IN ENDFB.MF4 FOR NEUTRONS OUT OF A REACTION
G0(E,EP) - IN ENDFB.MF5 FOR NEUTRONS OUT OF A REACTION
- IN ENDFB.M15 FOR PHOTONS OUT OF A REACTION

FOR NEUTRONS INCIDENT AND NEUTRONS EMITTED THIS DATA WILL BE OUTPUT IN MF=4 AND 5 FORMATS.

FOR NEUTRONS INCIDENT AND PHOTONS EMITTED THIS DATA WILL BE OUTPUT IN MF=15 FORMAT - THE SPECTRA ARE OUTPUT AND THE ANGULAR DISTRIBUTION IS IGNORED.

ALL PHOTON EMISSION IN THE ENDF/B-VI LIBRARY AS OF JANUARY 1992 IS ISOTROPIC AND AS SUCH NO DISTRIBUTION OF PHOTON ANGULAR DISTRIBUTIONS NEED BE OUTPUT - IT IS ALWAYS ISOTROPIC.

FOR ALL OTHER COMBINATIONS INCIDENT AND EMITTED PARTICLES THERE WILL BE NO ENDF/B FORMATTED OUTPUT.

VARIATIONS FROM ENDF/B MANUAL

LAW=1, LANG=2 = KALBACH-MANN

FOR THE DISTRIBUTIONS,

$$F(MU,E,EP) = G0(E,EP)*A*(COSH(MU*A)+R(E,EP)*SINH(MU*A))$$

G0(E,EP) = 1 - WHEN INTEGRATED OVER EP.

A*(COSH(MU*A)+R(E,EP)*SINH(MU*A)) = 2 - WHEN INTEGRATD OVER MU

THIS MEANS AS DEFINED IN THE ENDF/B MANUAL THE DISTRIBUTIONS ARE NORMALIZED TO 2, INSTEAD OF 1. IN ORDER TO OBTAIN CORRECTLY NORMALIZED DISTRIBUTIONS THE DISTRIBUTION SHOULD BE DEFINED TO INCLUDE A FACTOR OF 1/2 MULTIPLYING THE ANGULAR PART OF THE DISTRIBUTION.

$$F(MU,E,EP) = G0(E,EP)*0.5*A*(COSH(MU*A)+R(E,EP)*SINH(MU*A))$$

THIS IS THE FORM USED IN THIS CODE

LAW=1, ND NOT 0 = DISCRETE SECONDARY ENERGY DISTRIBUTION

THE ENDF/B MANUAL SAYS THESE ARE FLAGGED WITH NEGATIVE ENERGIES. IN ENDF/B-VI ALL OF THESE HAVE POSITIVE ENERGY. THIS CODE DOES NOT CONSIDER THE ENDF/B-VI DATA TO BE IN ERROR.

WITH THE CONVENTION ACTUALLY USED IN ENDF/B-VI ALL SECONDARY ENERGIES SHOULD BE NON-NEGATIVE AND IN ASCENDING ENERGY ORDER FOR EACH INCIDENT ENERGY.

FROM THE ENDF/B MANUAL IT IS NOT OBVIOUS WHAT G0(E,EP) SHOULD BE FOR DISCRETE PHOTONS - PHYSICALLY THIS IS A DELTA FUNCTION. IN ENDF/B-VI IT IS ENTERED AS 1.0 = INTERPRETING IT AS INTEGRATED OVER SECONDARY ENERGY - IN WHICH CASE THE DELTA FUNCTION = 1.0. Sixpak

LIMITATIONS Sixpak
========== Sixpak
CHECKING DATA Sixpak
============ Sixpak
THIS PROGRAM CHECKS ALL ENDF/B-VI MF=6 DATA. THE FOLLOWING CHECKS ARE PERFORMED. Sixpak

PARAMETERS Sixpak
========== Sixpak
ALL PARAMETERS ARE CHECKED FOR CONSISTENCY. IF PARAMETERS ARE NOT CONSISTENT THE PROGRAM MAY NOT BE ABLE TO PERFORM THE FOLLOWING TESTS AND WILL MERELY SKIP A SECTION OF DATA. Sixpak

INTERPOLATION LAWS Sixpak
================== Sixpak
ALL INTEGRATIONS ARE PERFORMED USING THE INTERPOLATION LAW GIVEN FOR SECONDARY ENERGY AND/OR COSINE. INTEGRATIONS ARE NOT PERFORMED OVER INCIDENT - ONLY INTEGRATION OVER SECONDARY ENERGY AND/OR COSINE ARE PERFORMED AT EACH INCIDENT ENERGY. THEREFORE THE INTERPOLATION LAW FOR INCIDENT ENERGY IS NOT USED BY THIS CODE. Sixpak

ALL INTERPOLATION LAWS ARE CHECKED. ALL DATA ASSOCIATED WITH INTERPOLATION LAWS ARE CHECKED, E.G., NO NON-NEGATIVE VALUES REQUIRING LOG INTERPOLATION. IN ORDER TO PERFORM REQUIRED INTEGRALS OVER COS AND EP IT IS IMPERATIVE THAT THE INTERPOLATION LAWS BE COMPATIBLE WITH THE DATA. Sixpak

ENDF/B-VI ALLOWS NEW INTERPOLATION LAWS FOR CORRESPONDING POINT AND UNIT BASE TRANSFORMATION INTERPOLATION. NONE OF THESE NEW INTERPOLATION LAWS ARE USED IN THE ENDF/B-VI LIBRARY AS OF JANUARY 1992 TO INTERPOLATE IN SECONDARY ENERGY OR COSINE. THEREFORE THIS PROGRAM CAN PERFORM ALL OF THE REQUIRED INTEGRALS OVER SECONDARY ENERGY AND/OR COSINE USING ONLY THE OLDER INTERPOLATION CODES. THIS PROGRAM ONLY PERFORMS INTEGRALS FOR EACH INCIDENT ENERGY, SO THAT INTERPOLATION IN INCIDENT ENERGY IS NOT PERFORMED BY THIS PROGRAM. Sixpak

NEW INTERPOLATION SCHEMES ARE USED FOR INCIDENT ENERGY - FOR EXAMPLE, CORRESPONDING POINT INTERPOLATION IS SPECIFIED TO ALLOW INTERPOLATION IN G0(E,EP) TO SIMULATE CASES WHERE THE INPUT ENERGY LIMIT IS DEFINED BY E-EP = A DIAGONAL CURVE ACROSS (E,EP) SPACE. THIS INTERPOLATION CODE CANNOT BE SPECIFIED IN THE MF=5 OUTPUT OF THIS CODE - MF=5 ONLY ALLOWS THE OLDER INTERPOLATION LAWS INT=1 THROUGH 5. THEREFORE THIS PROGRAM WILL USE THE CLOSEST CORRESPONDING INTERPOLATION CODE FOR OUTPUT TO MF=5. FOR USE WHERE THE OUTPUT OF THIS CODE = LOW ENERGY APPLICATIONS - THIS SHOULD HAVE LITTLE EFFECT ON RESULTS. Sixpak

FOR CONSISTENCY WITH EARLIER VERSIONS OF ENDF/B IN CREATING THE ENDF/B OUTPUT, IF ANY INPUT INTERPOLATION LAW IS NOT IN THE RANGE 1-5, IT WILL FIRST BE TESTED TO SEE IF MOD(10) IT IS IN THIS RANGE, FINALLY IF EVEN THIS DOESN'T WORK IT IS SET EQUAL TO 2 (LINEARLY INTERPOLATION). THIS METHOD WILL EFFECTIVELY REPLACE CORRESPONDING POINT AND UNIT BASE TRANSFORMATION BY THE CLOSEST RELATED INTERPOLATION LAW 1 THROUGH 5 - AGAIN NOTE, AS OF JANUARY 1992 NONE OF THESE NEW LAWS ARE USED IN ENDF/B-VI. IF THIS MUST BE DONE FOR INTERPOLATION IN SECONDARY ENERGY OR COSINE AN ERROR MESSAGE WILL BE PRINTED - SINCE THIS WOULD EFFECT THE ACCURACY OF THE INTEGRALS PERFORMED BY THIS PROGRAM. IF THIS MUST BE DONE FOR INCIDENT ENERGY NO MESSAGE IS PRINTED - SINCE THIS WILL NOT EFFECT THE ACCURACY OF THE INTEGRALS PERFORMED BY THIS PROGRAM. Sixpak

SPECTRA AND ANGULAR DISTRIBUTIONS Sixpak
================================= Sixpak

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

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

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. Sixpak

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

CREATING ENDF/B OUTPUT Sixpak
==========
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). Sixpak

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

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

ISOTROPIC PHOTON EMISSION Sixpak
==========
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. Sixpak

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

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. Sixpak

YIELD AND OUTPUT NORMALIZATION Sixpak
==========
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. Sixpak

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

LAW=1 Sixpak
=====
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 ENERGY (NEP=1) MAY BE GIVEN = A NORMALIZED DISTRIBUTION FOR A SINGLE DISCRETE EMISSION ENERGY. ALL OF THE ENDF/B-VI DATA AS OF JANUARY 1992 CONFORM TO THESE LIMITATIONS. Sixpak

SINCE THE FLAG NA, TO INDICATE ISOTROPIC DISTRIBUTIONS, IS ONLY GIVEN FOR EACH SECONDARY ENERGY (EP) THE PROGRAM CANNOT DECIDE IN ADVANCE WHETHER OR NOT THE DISTRIBUTION WILL BE ISOTROPIC AT ALL INCIDENT ENERGIES. THEREFORE ISOTROPIC DISTRIBUTIONS WILL BE OUTPUT EITHER: LANG = 1 - AS 1 LEGENDRE COEFFICIENT = 0.0 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 DISTRIBUTION).

DISCRETE PHOTONS ARE OUTPUT IN MF=15 AS 3 POINT DISTRIBUTIONS WITH SECONDARY ENERGY POINTS AT EP-DEP, EP, EP+DEP, WHERE DEP=0.001*EP. THE VALUES AT EP-DEP AND EP+DEP ARE 0.0, AND AT EP THE VALUE IS 1000.0/EP TO NORMALIZE THE DISTRIBUTION.

LAW=2
=====
NO LIMITATION ON REPRESENTATIONS.

LAW=3
=====
NO LIMITATION ON REPRESENTATIONS.

LAW=4
=====
NO OUTPUT - INCIDENT NEUTRON - EMITTED PHOTON OR NEUTRON REACTIONS ARE NOT EXPECTED.

LAW=5
=====
NO OUTPUT - INCIDENT NEUTRON - EMITTED PHOTON OR NEUTRON REACTIONS ARE NOT EXPECTED.

LAW=6
=====
NO OUTPUT - ENDF/B-VI ONLY INCLUDES 1 SECTION OF THIS TYPE OF DATA FOR (N,D) 2N,P.

LAW=7
=====
FOR EACH INCIDENT ENERGY THE REPRESENTATION MUST BE EITHER,

1) SQUARE = FOR EACH INCIDENT COSINE EXACTLY THE SAME SECONDARY ENERGIES.

2) LINEAR = FOR EACH INCIDENT COSINE THE INTERPOLATION LAW BETWEEN SECONDARY ENERGIES MUST BE LINEAR.

THESE 2 PRESENTATIONS ARE THE ONLY ONES PRESENTED IN ENDF/B-VI AS OF JANUARY 1992 - SO THIS PROGRAM CAN TRANSLATED ALL LAW=7 DATA FOR ENDF/B-VI.

LABORATORY VS. CENTER-OF-MASS SYSTEM
====================================

IN MANY CASES PEOPLE ASSUME THAT FOR HEAVY (HIGH ATOMIC WEIGHT) MATERIALS THE CENTER-OF-MASS AND LAB SYSTEMS ARE ALMOST IDENTICAL, SINCE IN THIS CASE THE CENTER-OF-MASS ENERGY WILL BE MUCH SMALLER THAN THE INCIDENT ENERGY. FOR A PROCESS SUCH AS ELASTIC SCATTERING WHERE FOR HEAVY MATERIALS THE SECONDARY ENERGY, EP, WILL ALWAYS BE A LARGE FRACTION OF THE INCIDENT ENERGY, THIS ASSUMPTION IS VALID. HOWEVER, FOR THE TYPICAL REACTIONS INCLUDED IN MF=6 THIS IS NOT ALWAYS TRUE - IN MANY OF THESE CASES THE SECONDARY ENERGY CAN EXTEND ALL THE WAY DOWN TO ZERO, AND IN PARTICULAR IT CAN BE SMALL COMPARED TO THE CENTER-OF-MASS ENERGY - WHICH MAKES THE TRANSFORMATION FROM CENTER-OF-MASS TO LAB IMPORTANT. THEREFORE GENERALLY TO TREAT MF=6 DATA WE MUST CONSIDER THIS TRANSFORMATION.

THE FOLLOWING DISCUSSING ONLY APPLIES TO SPECTRA THAT MAY BE OUTPUT IN MF=5 = ONLY DATA FOR NEUTRONS INCIDENT AND EMITTED - IN PARTICULAR THE FOLLOWING DEFINITIONS ARE NOT GENERAL - THEY ARE ONLY VALID FOR INCIDENT AND EMITTED NEUTRONS.

DOUBLE DIFFERENTIAL DATA IN MF=6 MAY BE GIVEN IN EITHER THE LAB OR C.M. SYSTEM. SIMILARLY ANGULAR DISTRIBUTIONS IN MF=4 MAY BE GIVEN IN EITHER THE LAB OR C.M. SYSTEM. IN CONTRAST ENERGY SPECTRA IN MF=5 CAN ONLY BE GIVEN IN THE LABORATORY SYSTEM.

THE ANGULAR DISTRIBUTIONS OUTPUT BY THIS CODE IN MF=4 ARE IN THE

SAME SYSTEM IN WHICH THEY ARE GIVEN IN MF=6 - EITHER LAB OR CENTER-OF-MASS SYSTEM.

THE ENERGY SPECTRA OUTPUT BY THIS CODE IN MF=5 MUST BE IN THE LAB SYSTEM - THIS IS THE ONLY ALLOWED FORM FOR MF=5 DATA.

FOR MF=6 SPECTRA GIVEN IN THE LAB SYSTEM THIS MERELY REQUIRES COPYING THE GIVEN SPECTRA TO MF=5 OUTPUT.

FOR MF=6 SPECTRA GIVEN IN THE CENTER-OF-MASS SYSTEM ONLY FIRST ORDER CORRECTIONS IN THE SPECTRA AND USED AND THEY ARE THEN OUTPUT IN MF=5 AS IN THE LAB SYSTEM - THE FIRST ORDER CORRECTIONS ARE DESCRIBED BELOW.

DEFINING,

MM = CENTER OF MASS MOTION
CM = OUTGOING (EMITTED) PARTICLE IN CENTER OF MASS
LAB = OUTGOING (EMITTED) PARTICLE IN LAB
THETA = CM SCATTERING ANGLE RELATIVE TO INCIDENT DIRECTION
COS(CM) = COSINE OF THE CM SCATTERING ANGLE

FOR NEUTRONS INCIDENT WITH AN ENERGY, E, AND THEREFORE A SPEED,

$$VN(E) = 2*SQRT(E)/MASS(IN)$$

THE CENTER-OF-MASS SPEED IS GIVEN BY,

$$V(MM) = VN(E)/(1 + A)$$

AND THE CENTER OF MASS ENERGY BY,

$$E(MM) = 1/2*MASS(IN)*V(MM)**2$$
$$= 1/2*MASS(IN)*VN(E)**2/(1 + A)**2$$
$$= E/(1 + A)**2$$

FOR DISTRIBUTIONS GIVEN IN MF=6 IN THE CM, THE SPEED, V(CM), SHOULD BE VECTORIALLY ADDED TO THAT OF OUTGOING PARTICLES TO DEFINE THE OUTGOING PARTICLES LAB VELOCITY, AND IN TURN IT'S ENERGY,

$$V(LAB)*COS(LAB) = V(MM) + V(CM)*COS(CM)$$
$$V(LAB)*SIN(LAB) = V(CM)*SIN(CM)$$

$$V(LAB)**2 = V(MM)**2 + V(CM)**2 + 2*COS(CM)*V(MM)*V(CM)$$

$$EP(LAB) = 0.5*MASS(OUT)*V(LAB)**2$$

$$= E(MM) + EP(CM) + 2*COS(CM)*SQRT(E(MM)*EP(CM))$$

WE CAN ALSO DEFINE THE REVERSE TRANSFORMATION USING,

$$V(CM)*COS(CM) = V(LAB)*COS(LAB) - V(MM)$$
$$V(CM)*SIN(CM) = V(LAB)*SIN(LAB)$$

$$V(CM)**2 = V(MM)**2 + V(LAB)**2 - 2*COS(LAB)*V(MM)*V(LAB)$$

$$EP(CM) = 0.5*MASS(OUT)*V(CM)**2$$

$$= E(MM) + EP(LAB) - 2*COS(LAB)*SQRT(E(MM)*EP(LAB))$$

WE CAN DEFINE COS(LAB) FROM THE RELATIONSHIP,

$$V(LAB)*COS(LAB) = V(MM) + V(CM)*COS(CM)$$

$$COS(LAB) = [V(MM) + V(CM)*COS(CM)]/V(LAB)$$

$$COS(LAB) = \frac{[V(MM) + V(CM)*COS(CM)]}{SQRT[V(MM)**2+V(CM)**2+2*COS(CM)*V(MM)*V(CM)]}$$

OR COS(CM) FROM THE RELATIONSHIP,

```
                                                                      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       Sixpak
THE CENTER-OF-MASS SYSTEM, EP(CM), IS MUCH LARGER THAN THE            Sixpak
ENERGY OF THE CENTER-OF-MASS, E(MM), THE CENTER-OF-MASS AND LAB       Sixpak
ENERGIES WILL BE ALMOST EQUAL - SIMILARLY FOR THE COSINE, IN          Sixpak
THIS CASE COS(LAB) AND COS(CM) WILL BE ALMOST EQUAL - HOWEVER,        Sixpak
FOR THE MF=6 DATA WE CANNOT ASSUME THAT THIS IS TRUE.                 Sixpak
                                                                      Sixpak
TO FIRST ORDER THE ANGULAR DEPENDENCE CAN BE IGNORED,                 Sixpak
                                                                      Sixpak
EP(LAB)   = E(MM) + EP(CM)                                            Sixpak
                                                                      Sixpak
ALL THIS SAYS IS THAT TO FIRST ORDER THE EFFECT OF TRANSFORMING       Sixpak
FROM THE CM TO LAB SYSTEM IS TO INCREASE THE ENERGY OF THE            Sixpak
EMITTED PARTICLE IN THE CENTER-OF-MASS SYSTEM BY THE ENERGY OF        Sixpak
THE CENTER-OF-MASS TO DEFINE THE LAB ENERGY.                          Sixpak
                                                                      Sixpak
NOT ONLY THE ENERGY, BUT ALSO THE SPECTRA MUST BE TRANSFORMED.        Sixpak
STARTING FROM THE DOUBLE DIFFERENTIAL DATA IN THE LAB SYSTEM,         Sixpak
F(E,EP,COS(LAB)), WE CAN DEFINE THE LAB SCALAR SPECTRUM AS,           Sixpak
                                                                      Sixpak
G0(E,EP) = INTEGRAL F(E,EP,COS(LAB))*D(COS(LAB))                      Sixpak
                                                                      Sixpak
THIS IS THE NORMAL CALCULATION DEFINED ABOVE AND USED FOR DATA        Sixpak
GIVEN IN THE LAB SYSTEM.                                              Sixpak
                                                                      Sixpak
STARTING FROM DATA IN THE CENTER OF MASS SYSTEM F(E,EP,COS(CM)),      Sixpak
WE CAN USE THE RELATIONSHIP,                                          Sixpak
                                                                      Sixpak
F(E,EP,COS(LAB))*D(COS(LAB)) = F(E,EP,COS(CM))*J*D(COS(LAB))          Sixpak
                                                                      Sixpak
J         = SQRT(EP(LAB)/EP(CM)) - THE JACOBIAN                       Sixpak
                                                                      Sixpak
          = E(MM)/EP(CM) + 1 + 2*COS(CM)*SQRT(E(MM)/EP(CM))           Sixpak
                                                                      Sixpak
AS IN THE CASE OF THE ENERGY, IN THIS FORM WE CAN SEE THAT AS         Sixpak
```

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.

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

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

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.

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.

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 BY E(MM) TO ACCOUNT FOR THE CENTER OF MASS MOTION - THE SPECTRA WILL NOT BE MODIFIED BY THE JACOBIAN FACTOR SQRT(EP(LAB)/EP(CM)) SINCE THIS WOULD REQUIRE A DETAILED TRANSFORMATION IN ENERGY AND COS(THETA) SPACE - WHICH IS JUDGED NOT TO BE WORTH PERFORMING WITHIN THE LIMITS OF WHERE THE OUTPUT FROM THIS CODE IS INTENDED TO BE USED.

SINCE THE ANGULAR DISTRIBUTION IS ALWAYS OUTPUT IN THE SAME SYSTEM AS WHICH IT IS GIVEN IN MF=6, NO TRANSFORMATION IS REQUIRED FOR THE MF=4 OUTPUT.

WHEN USED IN LOW ENERGY APPLICATIONS (E.G., FISSION REACTORS) THE HIGH ENERGY SPECTRA PRESENTED IN MF=6 WILL BE MOSTLY IMPORTANT SIMPLY IN CONSERVING PARTICLES, (E.G., AS IN (N,2N)) AND ENERGY AND THE DETAILS OF THE CORRELATION AND GROSS ENERGY SPECTRA WILL NOTE PLAY THAT IMPORTANT A ROLE. IN THIS CASE THE SPECTRA OUTPUT BY THIS PROGRAM IN MF=5 SHOULD BE ADEQUATE.

PLOTTAB FORMATTED OUTPUT

THIS PROGRAM CONTAINS ROUTINES TO PRODUCE OUTPUT THAT CAN BE USED AS INPUT TO THE PLOTTAB CODE TO OBTAIN GRAPHIC RESULTS.

THESE ROUTINES ARE DESIGNED ONLY FOR USE BY THE AUTHOR TO CHECK THIS CODE. USERS ARE ASKED NOT TO ACTIVATE OR TRY TO USE THESE ROUTINES. UNLESS YOU COMPLETELY UNDERSTAND THIS CODE THE RESULTS CAN BE UNRELIABLE IF YOU ACTIVATE THESE ROUTINES.

INPUT FILES

UNIT	DESCRIPTION
2	INPUT LINES (BCD - 80 CHARACTERS/RECORD)
10	ORIGINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)

OUTPUT FILES

UNIT	DESCRIPTION
3	OUTPUT REPORT (BCD - 120 CHARACTERS/RECORD)
11	ENDF/B DATA MF=4 (BCD - 80 CHARACTERS/RECORD)
12	ENDF/B DATA MF=5 (BCD - 80 CHARACTERS/RECORD)
14	ENDF/B DATA MF=15 (BCD - 80 CHARACTERS/RECORD)

```
  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
 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
```