```
========================================================================= 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
```

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
UNIVERSITY OF CALIFORNIA Sixpak
LAWRENCE LIVERMORE NATIONAL LABORATORY Sixpak
L-159 Sixpak
P.O. BOX 808 Sixpak
LIVERMORE, CA 94550 Sixpak
U.S.A. Sixpak
TELEPHONE 925-423-7359 Sixpak
E. MAIL CULLEN1@LLNL.GOV Sixpak
WEBSITE HTTP://WWW.LLNL.GOV/CULLEN1 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
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 COMPUTER.

PURPOSE

1) CHECK ALL DOUBLE-DIFFERENTIAL DATA (MF=6)

2) OUTPUT EQUIVALENT MF = 4, 5, 12, 14 AND 15 DATA.

DATA CHECKING

ALL OF THE ENDF/B-VI MF=6 DATA IS CHECKED - FOR DETAILS SEE BELOW.

THE MF=6 DATA IS NOT CORRECTED AND OUTPUT IN THE ENDF/B FORMAT. IT IS MERELY CHECKED. IF ERRORS ARE FOUND IT IS UP TO THE USER TO TAKE CORRECTIVE ACTION ON THE MF=6 DATA.

IN CONTRAST WHEN PROBLEMS ARE FOUND IN DATA WHICH WILL BE OUTPUT IN THE ENDF/B FORMAT (MF=4, 5, 12, 14 AND 15), WHENEVER POSSIBLE CORRECTIVE ACTION WILL BE TAKEN.

FURTHER CHECKS AND CORRECTIONS

ONCE THE DATA HAS BEEN OUTPUT IN MF = 4, 5, 12, 14 AND 15 FORMATS FURTHER CORRECTIVE ACTION CAN BE TAKEN AS FOLLOWS,

PROGRAM LEGEND

CAN BE USED TO CORRECT ANGULAR DISTRIBUTIONS WHICH ARE NEGATIVE, TO CONVERT FROM LEGENDRE COEFFICIENTS TO TABULATED ANGULAR DISTRIBUTIONS AND GENERALLY PERFORM MORE EXTENSIVE TESTS OF ALL MF=4 DATA.

PROGRAM EVALPLOT

VERSION 92-1 AND LATER VERSIONS CAN PLOT ALL OF THE MF=4, 5 AND 15 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. Sixpak

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

ENDF/B DATA OUTPUT ORDER Sixpak

Sixpak

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. Sixpak

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. Sixpak

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

Sixpak

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

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

SIG(E) = MF=3 CROSS SECTIONS Sixpak

Y(E) = YIELD (MULTIPLICITY) Sixpak
G0(E,EP) = ENERGY SPECTRUM Sixpak
F(E,EP,COS) = ANGULAR DISTRIBUTION Sixpak

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. Sixpak

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. Sixpak

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

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. Sixpak

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

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

BY THE UNCORRELATED DATA, Sixpak

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

BY INTEGRATING G0(E,EP)*F(E,EP,COS) OVER SECONDARY ENERGY (EP) Sixpak

TO DEFINE AN AVERAGE ANGULAR DISTRIBUTION, F0(E,COS). Sixpak
Sixpak
WHAT IS LOST IN THIS PROCESS IS THE CORRELATION BETWEEN EP AND COS Sixpak
SO THAT IN A TRANSPORT CALCULATION ALL MOMENTS OF THE FLUX WILL Sixpak
HAVE THE SAME SPECTRUM, G0(E,EP) AND EACH WILL BE EFFECTED BY THE Sixpak
AVERAGE ANGULAR DISTRIBUTION. Sixpak
Sixpak
FOR APPLICATIONS TO HIGH ENERGY FUSION APPLICATIONS CORRELATED Sixpak
DATA SHOULD BE USED. HOWEVER, FOR LOWER ENERGY APPLICATIONS, Sixpak
SUCH AS FISSION REACTORS, IT SHOULD BE ADEQUATE TO USE THE Sixpak
UNCORRELATED DATA - IN THIS CASE THE MOST IMPORTANT EFFECT Sixpak
WILL BE THE OVERALL NEUTRON MULTIPLICATION AND SPECTRUM. Sixpak
Sixpak
AN IMPORTANT CONSIDERATION IN DESIGNING THIS PROGRAM IS THAT Sixpak
MANY COMPUTER CODES - DATA PROCESSING AND TRANSPORT CODES - Sixpak
CANNOT USE THE CORRELATED (MF=6) DATA - NOR ARE THEY INTENDED Sixpak
FOR HIGH ENERGY USE. FOR THESE CODES THE UNCORRELATED DATA Sixpak
PRODUCED BY THIS CODE SHOULD BE ADEQUATE TO MEET THEIR NEEDS. Sixpak
Sixpak
WARNING - IT CANNOT BE STRESSED ENOUGH THAT THE OUTPUT OF THIS Sixpak
CODE SHOULD ONLY BE USED FOR LOW ENERGY APPLICATIONS - FAILURE Sixpak
TO HEED THIS WARNING CAN LEAD TO COMPLETELY UNRELIABLE RESULTS. Sixpak
Sixpak
ENDF/B FORMAT Sixpak
== Sixpak
THIS PROGRAM ONLY USES THE ENDF/B BCD OR CARD IMAGE FORMAT (AS Sixpak
OPPOSED TO THE BINARY FORMAT) AND CAN HANDLE DATA IN ANY VERSION Sixpak
OF THE ENDF/B FORMAT (I.E., ENDF/B-I, II,III, IV, V OR VI FORMAT). Sixpak
Sixpak
IT IS ASSUMED THAT THE DATA IS CORRECTLY CODED IN THE ENDF/B Sixpak
FORMAT AND NO ERROR CHECKING IS PERFORMED. IN PARTICULAR IT IS Sixpak
ASSUMED THAT THE MAT, MF AND MT ON EACH LINE IS CORRECT. SEQUENCE Sixpak
NUMBERS (COLUMNS 76-80) ARE IGNORED ON INPUT, BUT WILL BE Sixpak
CORRECTLY OUTPUT ON ALL LINES. THE FORMAT OF SECTION MF=1, MT=451 Sixpak
AND ALL SECTIONS OF MF=6 MUST BE CORRECT. THE PROGRAM SKIPS ALL Sixpak
OTHER SECTIONS OF DATA AND AS SUCH IS INSENSITIVE TO THE FORMAT Sixpak
OF ALL OTHER SECTIONS. Sixpak
Sixpak
CONTENTS OF OUTPUT Sixpak
== Sixpak
5 ENDF/B FORMATTED OUTPUT FILES ARE PRODUCED FOR NEUTRON INCIDENT Sixpak
DATA, Sixpak
Sixpak
1) ENDFB.MF4 - ANGULAR DISTRIBUTIONS AND LEGENDRE COEFFICIENTS Sixpak
FOR NEUTRONS Sixpak
2) ENDFB.MF5 - TABULATED NEUTRON ENERGY SPECTRA Sixpak
3) ENDFB.M12 - PHOTON EMISSION MULTIPLICITY Sixpak
4) ENDFB.M14 - PHOTON EMISSION ANGULAR DISTRIBUTIONS (ALWAYS Sixpak
ISOTROPIC) Sixpak
5) ENDFB.M15 - TABULATED PHOTON EMISSION SPECTRA Sixpak
Sixpak
EMITTED PARTICLE YIELD Sixpak
== Sixpak
NEUTRONS Sixpak
======== Sixpak
IN MF=6 THE YIELD FOR EACH REACTION IS THE ACTUAL MULTIPLICITY OF Sixpak
THE REACTION, E.G., (N,2N) = 2. IN USING MF=4 AND 5 DATA THE Sixpak
ENDF/B CONVENTION IS THAT THE MULTIPLICITY IS IMPLIED BY THE Sixpak
MT NUMBER, E.G., MT=16 = (N,2N) = 2. Sixpak
Sixpak
THE ONLY EXCEPT IN ENDF/B-VI IS MT=201 = TOTAL NEUTRON PRODUCTION Sixpak
WHERE AN ACTUAL ENERGY DEPENDENT YIELD IS INCLUDED IN MF=6. Sixpak
HOWEVER, IN THIS CASE THE MF=3 CROSS SECTION INCLUDES THE Sixpak

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 Sixpak
========== Sixpak
ALL OF THE DATA IN ENDF/B-VI, MF=6 ARE QUITE SMALL TABLES. AS SUCH Sixpak
THIS PROGRAM ONLY ALLOWS TABLES OF UP TO 12000 POINTS (12,000 X, Sixpak
Y VALUES). THIS SIZE IS MORE THAN ADEQUATE TO HANDLE ALL OF THE Sixpak
CURRENT ENDF/B-VI DATA, AND IT CAN BE EASILY INCREASED TO HANDLE Sixpak
ANY NEWER DATA AS IT BECOMES AVAILABLE. Sixpak
Sixpak
PLEASE CONTACT THE AUTHOR IF YOU HAVE AN EVALUATION WHICH EXCEEDS Sixpak
THIS LIMIT. Sixpak
Sixpak
SELECTION OF DATA Sixpak
========== Sixpak
THE PROGRAM SELECTS DATA TO BE PROCESSED BASED ON MAT/MT RANGES Sixpak
(MF=6 ASSUMED). THIS PROGRAM ALLOWS UP TO 100 MAT/MT RANGES TO BE Sixpak
SPECIFIED BY INPUT PARAMETERS. THE PROGRAM WILL ASSUME THAT THE Sixpak
ENDF/B TAPE IS IN MAT ORDER. THE PROGRAM WILL TERMINATE EXECUTION Sixpak
WHEN A MAT IS FOUND THAT IS ABOVE ALL REQUESTED MAT RANGES. Sixpak
Sixpak
PROGRAM OPERATION Sixpak
========== Sixpak
EACH SECTION (MT) OF MF=6 DATA IS SUBDIVIDED INTO SUBSECTIONS - Sixpak
ONE SUBSECTION FOR EACH EMITTED PARTICLE. Sixpak
Sixpak
EACH SUBSECTION OF DATA IS CONSIDERED SEPARATELY. EACH SUBSECTION Sixpak
OF ENDF/B MF=6 DATA TO PROCESS IS IN THE FORM, Sixpak
Sixpak
F(E,EP,COS) = SIG(E)*Y(E)*G0(E,EP)*F(E,EP,COS) Sixpak
Sixpak
SIG(E) = MF=3 CROSS SECTIONS Sixpak
Y(E) = YIELD (MULTIPLICITY) Sixpak
G0(E,EP) = ENERGY SPECTRUM Sixpak
F(E,EP,COS) = ANGULAR DISTRIBUTION Sixpak
Sixpak
G0(E,EP) = 1 WHEN INTEGRATED OVER EP (SECONDARY ENERGY) Sixpak
G0(E,EP)*F(E,EP,COS) = 1 WHEN INTEGRATED OVER EP AND COS Sixpak
Sixpak
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 LAWS BE COMPATIBLE WITH THE DATA.

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.

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.

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.

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.

Sixpak

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 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.

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 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. 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
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 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,

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

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

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

```
                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   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
```

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

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

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

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

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.

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     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
 18   ENDFB.M14                                                    Sixpak
 15   PLOTTAB.INP                                                  Sixpak
 16   PLOTTAB.CUR                                                  Sixpak
                                                                   Sixpak
                                                                   Sixpak
INPUT PARAMETERS                                                   Sixpak
================================================================== Sixpak
LINE  COLS.  DESCRIPTION                                           Sixpak
----  -----  -----------                                           Sixpak
   1   1-60  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
```