```
======================================================================SIGMA1
                                                                      SIGMA1
     PROGRAM SIGMA1                                                   SIGMA1
     ==============                                                   SIGMA1
     VERSION 73-1 (MARCH 1973)                                        SIGMA1
     VERSION 76-1 (FEBRUARY 1976)                                     SIGMA1
     VERSION 76-2 (OCTOBER 1976)                                      SIGMA1
     VERSION 77-1 (JANUARY 1977)                                      SIGMA1
     VERSION 78-1 (JULY 1978)                                         SIGMA1
     VERSION 79-1 (JULY 1979)    CDC-7600 AND CRAY-1 VERSION.         SIGMA1
     VERSION 80-1 (MAY 1980)     IBM, CDC AND CRAY VERSION            SIGMA1
     VERSION 80-2 (DECEMBER 1980)IMPROVED BASED ON USER COMMENTS.     SIGMA1
     VERSION 81-1 (MARCH 1981)   DOUBLE PRECISION IBM VERSION         SIGMA1
     VERSION 81-2 (AUGUST 1981)  IMPROVED IBM SPEED AND STABILITY     SIGMA1
     VERSION 82-1 (JANUARY 1982) IMPROVED COMPUTER COMPATIBILITY      SIGMA1
     VERSION 83-1 (JANUARY 1983)*MAJOR RE-DESIGN.                     SIGMA1
                                *PAGE SIZE INCREASED - 1002 TO 2004.  SIGMA1
                                *ELIMINATED COMPUTER DEPENDENT CODING.SIGMA1
                                *NEW, MORE COMPATIBLE I/O UNIT NUMBER.SIGMA1
                                *ADDED STANDARD ALLOWABLE ERROR OPTION SIGMA1
                                 (CURRENTLY 0.1 PER-CENT).            SIGMA1
                                *UNRESOLVED RESONANCE REGION COPIED.  SIGMA1
                                *1/V EXTENSION OF CROSS SECTIONS      SIGMA1
                                 OUTSIDE OF TABULATED ENERGY RANGE AND SIGMA1
                                 INTO UNRESOLVED ENERGY RANGE.        SIGMA1
     VERSION 83-2 (OCTOBER 1983)*IMPROVED BASED ON USER COMMENTS.     SIGMA1
     VERSION 84-1 (APRIL 1984)  *IMPROVED NUMERICAL STABILITY.        SIGMA1
                                *PARTIAL EVALUATION TREATMENT.        SIGMA1
     VERSION 85-1 (APRIL 1985)  *ITERATE TO CONVERGENCE (USING THE SAMESIGMA1
                                 ENERGY GRID FOR HOT CROSS SECTION AS SIGMA1
                                 COLD CROSS SECTIONS WAS FOUND TO BE  SIGMA1
                                 INACCURATE).                         SIGMA1
                                *NEW FASTER HIGH ENERGY BROADENING.   SIGMA1
                                *UPDATED FOR ENDF/B-6  FORMATS.       SIGMA1
                                *SPECIAL I/O ROUTINES TO GUARANTEE    SIGMA1
                                 ACCURACY OF ENERGY.                  SIGMA1
                                *DOUBLE PRECISION TREATMENT OF ENERGY SIGMA1
                                 (REQUIRED FOR NARROW RESONANCES).    SIGMA1
     VERSION 85-2 (AUGUST 1985) *FORTRAN-77/H VERSION                 SIGMA1
     VERSION 86-1 (JANUARY 1986)*ENERGY DEPENDENT SCATTERING RADIUS   SIGMA1
     VERSION 88-1 (JULY 1988)   *OPTION...INTERNALLY DEFINE ALL I/O   SIGMA1
                                 FILE NAMES (SEE, SUBROUTINE FILEIO   SIGMA1
                                 FOR DETAILS).                        SIGMA1
                                *IMPROVED BASED ON USER COMMENTS.     SIGMA1
     VERSION 89-1 (JANUARY 1989)*PSYCHOANALYZED BY PROGRAM FREUD TO   SIGMA1
                                 INSURE PROGRAM WILL NOT DO ANYTHING  SIGMA1
                                 CRAZY.                               SIGMA1
                                *UPDATED TO USE NEW PROGRAM CONVERT   SIGMA1
                                 KEYWORDS.                            SIGMA1
                                *ADDED LIVERMORE CIVIC COMPILER       SIGMA1
                                 CONVENTIONS.                         SIGMA1
     VERSION 90-1 (JUNE 1990)   *UPDATED BASED ON USER COMMENTS       SIGMA1
                                *ADDED FORTRAN SAVE OPTION            SIGMA1
                                *NEW MORE CONSISTENT ENERGY OUTPUT    SIGMA1
                                 ROUTINES                             SIGMA1
     VERSION 91-1 (JULY 1991)   *WARNING...INPUT PARAMETER FORMAT     SIGMA1
                                 HAS BEEN CHANGED - SEE BELOW FOR     SIGMA1
                                 DETAILS.                             SIGMA1
                                *ADDED CHARGED PARTICLE PROJECTILES   SIGMA1
                                *OUTPUT ENERGY RANGE IS ALWAYS AT     SIGMA1
                                 LEAST AS LARGE AS INPUT ENERGY RANGE.SIGMA1
                                *NO 1/V EXTENSION OF CROSS SECTIONS   SIGMA1
                                 FROM UNRESOLVED ENERGY RANGE.        SIGMA1
     VERSION 92-1 (JANUARY 1992)*INSURE MINIMUM AND MAXIMUM CROSS     SIGMA1
                                 SECTIONS ARE ALWAYS KEPT (NOT THINNED)SIGMA1
                                *MT=19 (FIRST CHANCE FISSION) TREATED SIGMA1
                                 THE SAME AS FISSION.                 SIGMA1
                                *VARIABLE MINIMUM CROSS SECTION OF    SIGMA1
                                 INTEREST - TO ALLOW SMALL CROSS      SIGMA1
                                 SECTIONS NEAR THRESHOLDS TO BE       SIGMA1
                                 TREATED PROPERLY.                    SIGMA1
```

```
                          *ALL ENERGIES INTERNALLY ROUNDED PRIOR SIGMA1
                           TO CALCULATIONS.                     SIGMA1
                          *COMPLETELY CONSISTENT I/O AND ROUNDINGSIGMA1
                           ROUTINES - TO MINIMIZE COMPUTER      SIGMA1
                           DEPENDENCE.                          SIGMA1
VERSION 92-2 (JULY 1992)  *CORRECTED BUG ASSOCIATED WITH       SIGMA1
                           THRESHOLD REACTIONS.                 SIGMA1
                          *UNRESOLVED REGION COPIED WITHOUT     SIGMA1
                           THINNING (IT SHOULD BE EXACTLY THE   SIGMA1
                           SAME AT ALL TEMPERATURES).           SIGMA1
                          *NO THINNING OF REACTIONS (MT) THAT   SIGMA1
                           WERE NOT BROADENED.                  SIGMA1
VERSION 93-1 (APRIL 1993) *INCREASED PAGE SIZE FROM 2004       SIGMA1
                           TO 24000 ENERGY PONTS.               SIGMA1
VERSION 94-1 (JANUARY 1994)*VARIABLE ENDF/B DATA FILENAMES     SIGMA1
                           TO ALLOW ACCESS TO FILE STRUCTURES   SIGMA1
                           (WARNING - INPUT PARAMETER FORMAT    SIGMA1
                           HAS BEEN CHANGED)                    SIGMA1
                          *CLOSE ALL FILES BEFORE TERMINATING   SIGMA1
                           (SEE, SUBROUTINE ENDIT)              SIGMA1
VERSION 96-1 (JANUARY 1996) *COMPLETE RE-WRITE                 SIGMA1
                           *IMPROVED COMPUTER INDEPENDENCE      SIGMA1
                           *ALL DOUBLE PRECISION                SIGMA1
                           *ON SCREEN OUTPUT                    SIGMA1
                           *UNIFORM TREATMENT OF ENDF/B I/O     SIGMA1
                           *IMPROVED OUTPUT PRECISION           SIGMA1
                           *DEFINED SCRATCH FILE NAMES          SIGMA1
                           *ALWAYS INCLUDE THERMAL VALUE        SIGMA1
VERSION 97-1 (APRIL 1997)  *OPTIONALLY SET NEGATIVE CROSS       SIGMA1
                            SECTIONS = 0 ON INPUT AND           SIGMA1
                            OUTPUT.                             SIGMA1
                           *INCREASED PAGE SIZE FROM 24000      SIGMA1
                            TO 60000 ENERGY POINTS.             SIGMA1
VERSION 99-1 (MARCH 1999)  *CORRECTED CHARACTER TO FLOATING     SIGMA1
                            POINT READ FOR MORE DIGITS          SIGMA1
                           *UPDATED TEST FOR ENDF/B FORMAT      SIGMA1
                            VERSION BASED ON RECENT FORMAT CHANGESIGMA1
                           *TREAT LOW ENERGY INITIAL CROSS      SIGMA1
                            SECTIONS AS LOG-LOG INTERPOLABLE    SIGMA1
                           *CONSTANT (RATHER THAN 1/V) EXTENSION SIGMA1
                            TO HIGHER ENERGY.                   SIGMA1
                           *UPDATED CONSTANTS BASED ON CSEWG    SIGMA1
                            SUBCOMMITTEE RECOMMENDATIONS        SIGMA1
                           *GENERAL IMPROVEMENTS BASED ON       SIGMA1
                            USER FEEDBACK                       SIGMA1
VERSION 99-2 (JUNE 1999)   *EXTENDED RANGE OF INTEGRALS FROM 4  SIGMA1
                            TO 5 UNITS ON EACH SIDE OF ENERGY   SIGMA1
                            POINT TO ALLOW FOR LARGER VARIATION SIGMA1
                            IN THE LOCAL CROSS SECTION          SIGMA1
                           *ASSUME ENDF/B-6, NOT 5, IF MISSING  SIGMA1
                            MF=1, MT-451.                       SIGMA1
VERSION 99-3 (OCTOBER 1999))*IMPROVED ERFC FUNCTION DEFINITION. SIGMA1
                            I THANK BOB MACFARLANE (LANL) FOR   SIGMA1
                            SUPPLYING A MORE ACCURATE ERFC      SIGMA1
                            FUNCTION.                           SIGMA1
VERS. 2000-1 (FEBRUARY 2000)*CORRECTED LOW ENERGY INTERPOLATION SIGMA1
                            FOR NON-POSITIVE CROSS SECTIONS     SIGMA1
                           *GENERAL IMPROVEMENTS BASED ON       SIGMA1
                            USER FEEDBACK                       SIGMA1
VERS. 2002-1 (MAY 2002)    *OPTIONAL INPUT PARAMETERS           SIGMA1
VERS. 2004-1 (JAN. 2004)   *OPTIONALLY IGNORE UNRESOLVED REGION  SIGMA1
                           *CORRECTED PROBLEM AT THE RESOLVED/  SIGMA1
                            UNRESOLVED ENERGY BOUNDARY.         SIGMA1
                           *CORRECTED HIGH ENERGY CONSTANT CROSS SIGMA1
                            SECTION EXTENSION.                  SIGMA1
                           *TIGHTER CRITERIA FOR INITIAL ENERGY  SIGMA1
                            POINT SPACING                       SIGMA1
                           *TEMPERATURE DEPENDENT ENERGY POINT   SIGMA1
                            SPACING.                            SIGMA1
                           *ADDED NEW REICH-MOORE (LRF=7) TO    SIGMA1
                            FILE2 TO ALLOW COPY TO FIND ANY     SIGMA1
```

```
                          FOLLOWING UNRESOLVED PARAMETERS      SIGMA1
VERS. 2005-1 (JUNE 2005)  *CORRECTED ERROR IN EHOT3 EQUIVALENCE SIGMA1
                          TO EHOT - THIS ONLY EFFECTS VERY BIG SIGMA1
                          OUTPUT FILES.                        SIGMA1
VERS. 2007-1 (JAN. 2007)  *CHECKED AGAINST ALL ENDF/B-6.       SIGMA1
                          *INCREASED PAGE SIZE FROM 60,000     SIGMA1
                          TO 360,000 ENERGY POINTS.            SIGMA1
VERS. 2008-1 (APRIL 2008) *1/2 INITIAL ENERGY POINT SPACING    SIGMA1
                          *72 CHARACTER FILE NAMES.            SIGMA1
VERS. 2010-1 (Apr. 2010)  *ASSUME LOW ENERGY LOG-LOG VARIATION SIGMA1
                          UP TO 1/A (eV) FOR ALL BUT TOTAL AND SIGMA1
                          ELASTIC.                             SIGMA1
                          *CHANGED DEFAULT UNCERTAINTY TO 0.01% SIGMA1
                          FROM 0.1%                            SIGMA1
                          *ALLOW MULTIPLE, ADJACENT UNRESOLVED SIGMA1
                          RESONANCE REGIONS = COMBINE INTO ONE SIGMA1
                          LARGER ENERGY RANGE TO COPY.         SIGMA1
                          *DO NOT BROADEN SECTIONS THAT START  SIGMA1
                          ABOVE 1 MILLION KT - PREVIOUSLY IT   SIGMA1
                          WAS ASSUMED TOTAL, ELASTIC, CAPTURE  SIGMA1
                          AND FISSION, AND LARGE SECTIONS (OVERSIGMA1
                          10,000 ENERGY POINTS) WOULD BROADEN. SIGMA1
VERS. 2012-1 (Aug. 2012)  *CHANGE COPY CRITERIA TO HANDLE NEW  SIGMA1
                          (N,N') DATA = THRESHOLD MAY BE VERY  SIGMA1
                          HIGH (OLD CRITERIA) BUT INCLUDES MANYSIGMA1
                          TABULATED ENERGY POINTS (NEW ADDED   SIGMA1
                          CRITERIA).                           SIGMA1
                          *ADDED STOP IF INCIDENT PARTICLE DATA SIGMA1
                          CANNOT BE DOPPLER BROADENED, E.G.,   SIGMA1
                          PHOTON INCIDENT.                     SIGMA1
                          *Added CODENAME                      SIGMA1
                          *32 and 64 bit Compatible            SIGMA1
                          *Added ERROR stop                    SIGMA1
VERS. 2013-1 (Nov. 2013)  *Added NO broadening above 10 MeV -  SIGMA1
                          this is to handle newer evaluations  SIGMA1
                          that extend to higher energies and   SIGMA1
                          may do "strange" things to stop one  SIGMA1
                          MT and then include it as part of    SIGMA1
                          a sum at higher energies, e.g. this  SIGMA1
                          change will copy ALL points above    SIGMA1
                          10 MeV, thus avoiding problems near  SIGMA1
                          transistion energies at 20. 30, etc. SIGMA1
                          MeV or higher energies.              SIGMA1
VERS. 2015-1 (Jan. 2015)  *Replaced ALL 3 way IF Statements.   SIGMA1
                          *Replaced ALL LOGICAL by INTEGER.    SIGMA1
                          *Extended OUT9.                      SIGMA1
VERS. 2017-1 (May  2017)  *For MF=2 only use MT=151 = Defines  SIGMA1
                          Unresolved Resonance Region (URR).   SIGMA1
                          Ignore - NJOY created MT=152 and 153.SIGMA1
                          *Increased page size to 1,2000,000.  SIGMA1
                          *All floating input parameters changedSIGMA1
                          to character input + IN9 conversion. SIGMA1
                          *Added NRO = energy dependent scatter SIGMA1
                          radius to copying FILE2 parameters   SIGMA1
                          to define unresolved energy range.   SIGMA1
                          *Corrected energy dependent scatteringSIGMA1
                          radius for all resonance types (see, SIGMA1
                          the above comments).                 SIGMA1
VERS. 2018-1 (Nov. 2018)  *Added on-line report for ALL ENDERRORSIGMA1
VERS. 2019-1 (June 2019)  *Terminate if MF=3 Point Count and   SIGMA1
                          Interpolation Law do not agree.      SIGMA1
                          *Terminate if MF=3 Background        SIGMA1
                          Interpolation is NOT Linear.         SIGMA1
                          *Terminate if MF/MT=1/451 Input      SIGMA1
                          temperature exceeds requested        SIGMA1
                          Temperature - otherwise the output   SIGMA1
                          by this code to MF=3 would appear    SIGMA1
                          to be at the WRONG temperature.      SIGMA1
                          *Additional Interpolation Law Tests  SIGMA1
                          *Check consistency of Maximum        SIGMA1
                          Tabulated cross sections for ALL MT  SIGMA1
```

```
                           processed - print WQARNING if NOT    SIGMA1
                           the same for ALL MTs.                SIGMA1
VERS. 2020-1 (Dec. 2020)   *Complete Re-write of convergence    SIGMA1
                           *Replaced INCORE9 by INCORE10.       SIGMA1
                           *Updated minimum/maximum convergence SIGMA1
                           procedure.                           SIGMA1
                           *Added Target Isomer State           SIGMA1
                           *Check Atomic Weight > 0             SIGMA1
VERS. 2021-1 (Mar. 2021)   *Updated for FORTRAN 2018            SIGMA1
                           *Minimum Cross Section is no longer  SIGMA1
                           an input option - set to 1.0d-30.    SIGMA1
VERS. 2023-1 (Feb. 2023)   *Decreased page size from 1,200,000  SIGMA1
                           to 120,000.                          SIGMA1
                                                                SIGMA1
OWNED, MAINTAINED AND DISTRIBUTED BY                            SIGMA1
-----------------------------------                             SIGMA1
THE NUCLEAR DATA SECTION                                        SIGMA1
INTERNATIONAL ATOMIC ENERGY AGENCY                              SIGMA1
P.O. BOX 100                                                    SIGMA1
A-1400, VIENNA, AUSTRIA                                         SIGMA1
EUROPE                                                          SIGMA1
                                                                SIGMA1
ORIGINALLY WRITTEN BY                                           SIGMA1
-------------------------------------                           SIGMA1
Dermott E. Cullen                                               SIGMA1
                                                                SIGMA1
PRESENT CONTACT INFORMATION                                     SIGMA1
---------------------------                                     SIGMA1
Dermott E. Cullen                                               SIGMA1
1466 Hudson Way                                                 SIGMA1
Livermore, CA 94550                                             SIGMA1
U.S.A.                                                          SIGMA1
Telephone  925-443-1911                                         SIGMA1
E. Mail    RedCullen1@Comcast.net                               SIGMA1
Website    RedCullen1.nedt/HOMEPAGE.NEW                         SIGMA1
                                                                SIGMA1
Acknowledgement 2004                                            SIGMA1
--------------------                                            SIGMA1
Currently almost all improvements to this code are based upon   SIGMA1
feedback from code users who report problems. This feedback     SIGMA1
benefits ALL users of this code, and ALL users are encouraged   SIGMA1
to report problems.                                             SIGMA1
                                                                SIGMA1
Improvements on the 2004 version of this code based on user     SIGMA1
feedback including,                                             SIGMA1
1) Bret Beck  - reported a problem at the resolved/unresolved   SIGMA1
                energy boundary.                                SIGMA1
2) S. Ganesan - reported a problem for small temperature changes. SIGMA1
                                                                SIGMA1
AUTHORS MESSAGE                                                 SIGMA1
---------------                                                 SIGMA1
THE REPORT DESCRIBED ABOVE IS THE LATEST PUBLISHED DOCUMENTATION  SIGMA1
FOR THIS PROGRAM. HOWEVER, THE COMMENTS BELOW SHOULD BE CONSIDEREDSIGMA1
THE LATEST DOCUMENTATION INCLUDING ALL RECENT IMPROVEMENTS. PLEASESIGMA1
READ ALL OF THESE COMMENTS BEFORE IMPLEMENTATION, PARTICULARLY  SIGMA1
THE COMMENTS CONCERNING MACHINE DEPENDENT CODING.               SIGMA1
                                                                SIGMA1
AT THE PRESENT TIME WE ARE ATTEMPTING TO DEVELOP A SET OF COMPUTERSIGMA1
INDEPENDENT PROGRAMS THAT CAN EASILY BE IMPLEMENTED ON ANY ONE  SIGMA1
OF A WIDE VARIETY OF COMPUTERS. IN ORDER TO ASSIST IN THIS PROJECTSIGMA1
IT WOULD BE APPECIATED IF YOU WOULD NOTIFY THE AUTHOR OF ANY    SIGMA1
COMPILER DIAGNOSTICS, OPERATING PROBLEMS OR SUGGESTIONS ON HOW TO SIGMA1
IMPROVE THIS PROGRAM. HOPEFULLY, IN THIS WAY FUTURE VERSIONS OF SIGMA1
THIS PROGRAM WILL BE COMPLETELY COMPATIBLE FOR USE ON YOUR      SIGMA1
COMPUTER.                                                       SIGMA1
                                                                SIGMA1
PURPOSE                                                         SIGMA1
-------                                                         SIGMA1
THIS PROGRAM IS DESIGNED TO DOPPLER BROADEN NEUTRON INDUCED     SIGMA1
CROSS SECTIONS. EACH SECTION OF CROSS SECTIONS (FILE 3) IS READ SIGMA1
FROM THE ENDF/B FORMAT. THE DATA IS DOPPLER BROADENED, THINNED  SIGMA1
```

AND OUTPUT IN THE ENDF/B FORMAT. SIGMA1

IN THE FOLLOWING DISCUSSION FOR SIMPLICITY THE ENDF/B TERMINOLOGY SIGMA1
---ENDF/B TAPE---WILL BE USED. IN FACT THE ACTUAL MEDIUM MAY BE SIGMA1
TAPE, CARDS, DISK OR ANY OTHER MEDIUM. SIGMA1

ENDF/B FORMAT SIGMA1
------------ SIGMA1
THIS PROGRAM ONLY USES THE ENDF/B BCD OR CARD IMAGE FORMAT (AS SIGMA1
OPPOSED TO THE BINARY FORMAT) AND CAN HANDLE DATA IN ANY VERSION SIGMA1
OF THE ENDF/B FORMAT (I.E., ENDF/B-1, 2, 3, 4, 5, 6 FORMAT). SIGMA1

IT IS ASSUMED THAT THE DATA IS CORRECTLY CODED IN THE ENDF/B SIGMA1
FORMAT AND NO ERROR CHECKING IS PERFORMED. IN PARTICULAR IT IS SIGMA1
ASSUMED THAT THE MAT, MF AND MT ON EACH CARD IS CORRECT. SEQUENCE SIGMA1
NUMBERS (COLUMNS 76-80) ARE IGNORED ON INPUT, BUT WILL BE SIGMA1
CORRECTLY OUTPUT ON ALL CARDS. THE FORMAT OF SECTION MF=1, MT=451 SIGMA1
AND ALL SECTIONS OF MF=3 MUST BE CORRECT. THE PROGRAM COPIES ALL SIGMA1
OTHER SECTION OF DATA AS HOLLERITH AND AS SUCH IS INSENSITIVE TO SIGMA1
THE CORRECTNESS OR INCORRECTNESS OF ALL OTHER SECTIONS. SIGMA1

ALL CROSS SECTIONS THAT ARE USED BY THIS PROGRAM MUST BE TABULATEDSIGMA1
AND LINEARLY INTERPOLABLE IN ENERGY AND CROSS SECTION (ENDF/B SIGMA1
INTERPOLATION LAW 2). FILE 3 CROSS SECTIONS MAY BE MADE LINEARLY SIGMA1
INTERPOLABLE BY USING PROGRAM LINEAR (UCRL-50400, VOL.17, PART A).SIGMA1
FILE 2 RESONANCE PARAMETERS MAY BE USED TO RECONSTRUCT ENERGY SIGMA1
DEPENDENT CROSS SECTIONS AND ADD IN FILE 3 BACKGROUND CROSS SIGMA1
SECTIONS TO DEFINE LINEARLY INTERPOLABLE CROSS SECTIONS BY USING SIGMA1
PROGRAM RECENT (UCRL-50400, VOL. 17, PART C). IF THIS PROGRAM SIGMA1
FINDS THAT THE FILE 3 CROSS SECTIONS ARE NOT LINEARLY INTERPOLABLESIGMA1
THIS PROGRAM WILL TERMINATE EXECUTION. SIGMA1

UNRESOLVED RESONANCE REGION SIGMA1
--------------------------- SIGMA1
IN THE UNRESOLVED RESONANCE REGION IT IS NOT POSSIBLE TO EXACTLY SIGMA1
DEFINE THE ENERGY DEPENDENCE OF THE CROSS SECTIONS. THE AVERAGE SIGMA1
WIDTHS AND SPACINGS GIVEN IN ENDF/B ARE ONLY ADEQUATE TO DEFINE SIGMA1
AVERAGE VALUES OF THE CROSS SECTIONS. THEREFORE ALL CROSS SECTIONSSIGMA1
IN THE ENDF/B FORMAT FOR THE UNRESOLVED REGION ARE REALLY AVERAGE SIGMA1
VALUES WHICH CANNOT BE DOPPLER BROADENED USING THE SIGMA1 METHOD SIGMA1
(WHICH REQUIRES TABULATED, LINEARLY INTERPOLABLE, ENERGY DEPENDENTSIGMA1
CROSS SECTIONS. SIGMA1

THEREFORE, SIGMA1
(1) ALL TABULATED POINTS WITHIN THE UNRESOLVED RESONANCE REGION SIGMA1
WILL BE COPIED, WITHOUT MODIFICATION OR BROADENING. ADOPTION OF SIGMA1
THIS CONVENTION WILL ALLOW SUBSEQUENT PROGRAMS TO PROPERLY DEFINE SIGMA1
SELF-SHIELDED, DOPPLER BROADENED CROSS SECTIONS IN THE UNRESOLVED SIGMA1
RESONANCE REGION. SIGMA1
(2) CROSS SECTIONS WILL BE EXTENDED AS 1/V ABOVE THE UPPER ENERGY SIGMA1
LIMIT OF THE RESOLVED RESONANCE REGION AND BELOW THE LOWER ENERGY SIGMA1
LIMIT OF THE CONTINUUUM REGION (I.E. INTO THE UNRESOLVED SIGMA1
RESONANCE REGION). THIS CONVENTION WILL GUARANTEE A SMOOTH SIGMA1
BEHAVIOR CLOSE TO THE UNRESOLVED RESONANCE REGION BOUNDARIES. SIGMA1

OUTPUT FORMAT SIGMA1
------------- SIGMA1
IN THIS VERSION OF SIGMA1 ALL FILE 3 ENERGIES WILL BE OUTPUT IN SIGMA1
F (INSTEAD OF E) FORMAT IN ORDER TO ALLOW ENERGIES TO BE WRITTEN SIGMA1
WITH UP TO 9 DIGITS OF ACCURACY. IN PREVIOUS VERSIONS THIS WAS AN SIGMA1
OUTPUT OPTION. HOWEVER USE OF THIS OPTION TO COMPARE THE RESULTS SIGMA1
OF ENERGIES WRITTEN IN THE NORMAL ENDF/B CONVENTION OF 6 DIGITS SIGMA1
TO THE 9 DIGIT OUTPUT FROM THIS PROGRAM DEMONSTRATED THAT FAILURE SIGMA1
TO USE THE 9 DIGIT OUTPUT CAN LEAD TO LARGE ERRORS IN THE DATA SIGMA1
JUST DUE TO TRANSLATION OF THE ENERGIES TO THE ENDF/B FORMAT. SIGMA1

CONTENTS OF OUTPUT SIGMA1
------------------ SIGMA1
ENTIRE EVALUATIONS ARE OUTPUT, NOT JUST THE BROADENED FILE 3 SIGMA1
CROSS SECTIONS, E.G. ANGULAR AND ENERGY DISTRIBUTIONS ARE ALSO SIGMA1
INCLUDED. SIGMA1

```
                                                                      SIGMA1
DOCUMENTATION                                                         SIGMA1
-------------                                                         SIGMA1
THE FACT THAT THIS PROGRAM HAS OPERATED ON THE DATA IS DOCUMENTED     SIGMA1
BY THE ADDITION OF THREE COMMENTS CARDS AT THE END OF EACH            SIGMA1
HOLLERITH SECTION IN THE FORM                                         SIGMA1
                                                                      SIGMA1
***************** PROGRAM SIGMA1 (2023-1) ***************           SIGMA1
DATA DOPPLER BROADENED TO 300.0   KELVIN AND                         SIGMA1
DATA THINNED TO WITHIN AN ACCURACY OF  0.1 PER-CENT                   SIGMA1
                                                                      SIGMA1
THE ORDER OF ALL SIMILAR COMMENTS (FROM LINEAR,RECENT AND GROUPY)     SIGMA1
REPRESENTS A COMPLETE HISTORY OF ALL OPERATIONS PERFORMED ON          SIGMA1
THE DATA.                                                             SIGMA1
                                                                      SIGMA1
THESE COMMENT CARDS ARE ONLY ADDED TO EXISTING HOLLERITH SECTIONS,    SIGMA1
I.E., THIS PROGRAM WILL NOT CREATE A HOLLERITH SECTION. THE FORMAT    SIGMA1
OF THE HOLLERITH SECTION IN ENDF/B-5 DIFFERS FROM THE THAT OF         SIGMA1
EARLIER VERSIONS OF ENDF/B. BY READING AN EXISTING MF=1, MT=451       SIGMA1
IT IS POSSIBLE FOR THIS PROGRAM TO DETERMINE WHICH VERSION OF         SIGMA1
THE ENDF/B FORMAT THE DATA IS IN. WITHOUT HAVING A SECTION OF         SIGMA1
MF=1, MT=451 PRESENT IT IS IMPOSSIBLE FOR THIS PROGRAM TO             SIGMA1
DETERMINE WHICH VERSION OF THE ENDF/B FORMAT THE DATA IS IN, AND      SIGMA1
AS SUCH IT IS IMPOSSIBLE FOR THE PROGRAM TO DETERMINE WHAT FORMAT     SIGMA1
SHOULD BE USED TO CREATE A HOLLERITH SECTION.                         SIGMA1
                                                                      SIGMA1
REACTION INDEX                                                        SIGMA1
--------------                                                        SIGMA1
THIS PROGRAM DOES NOT USE THE REACTION INDEX WHICH IS GIVEN IN        SIGMA1
SECTION MF=1, MT=451 OF EACH EVALUATION.                              SIGMA1
                                                                      SIGMA1
THIS PROGRAM DOES NOT UPDATE THE REACTION INDEX IN MF=1, MT=451.      SIGMA1
THIS CONVENTION HAS BEEN ADOPTED BECAUSE MOST USERS DO NOT            SIGMA1
REQUIRE A CORRECT REACTION INDEX FOR THEIR APPLICATIONS AND IT WAS    SIGMA1
NOT CONSIDERED WORTHWHILE TO INCLUDE THE OVERHEAD OF CONSTRUCTING     SIGMA1
A CORRECT REACTION INDEX IN THIS PROGRAM. HOWEVER, IF YOU REQUIRE     SIGMA1
A REACTION INDEX FOR YOUR APPLICATIONS, AFTER RUNNING THIS PROGRAM    SIGMA1
YOU MAY USE PROGRAM DICTIN TO CREATE A CORRECT REACTION INDEX.        SIGMA1
                                                                      SIGMA1
SECTION SIZE                                                          SIGMA1
------------                                                          SIGMA1
SINCE THIS PROGRAM USES A LOGICAL PAGING SYSTEM THERE IS NO LIMIT     SIGMA1
TO THE NUMBER OF POINTS IN ANY SECTION, E.G., THE TOTAL CROSS         SIGMA1
SECTION MAY BE REPRESENTED BY 200,000 DATA POINTS.                    SIGMA1
                                                                      SIGMA1
SELECTION OF DATA                                                     SIGMA1
-----------------                                                     SIGMA1
THE PROGRAM SELECTS MATERIALS TO BE BROADENED BASED EITHER ON         SIGMA1
MAT (ENDF/B MAT NO.) OR ZA. THE PROGRAM ALLOWS UP TO 100 MAT OR       SIGMA1
ZA RANGES TO BE SPECIFIED. THE PROGRAM WILL ASSUME THAT THE           SIGMA1
ENDF/B TAPE IS IN EITHER MAT OR ZA ORDER, WHICHEVER CRITERIA IS       SIGMA1
USED TO SELECT MATERIALS, AND WILL TERMINATE WHEN A MAT OR ZA         SIGMA1
IS FOUND THAT IS ABOVE THE RANGE OF ALL REQUESTS.                     SIGMA1
                                                                      SIGMA1
ENERGY GRID OF BROADENED DATA                                         SIGMA1
-----------------------------                                         SIGMA1
THE ENERGY GRID FOR THE DOPPLER BROADENED CROSS SECTIONS IS           SIGMA1
SELECTED TO INSURE THAT THE BROADENED DATA IS LINEAR-LINEAR           SIGMA1
INTERPOLABLE. AS SUCH THE ENERGY GRID FOR THE BROADENED DATA          SIGMA1
MAY NOT BE THE SAME AS THE ENERGY GRID FOR THE ORIGINAL               SIGMA1
UNBROADENED DATA. GENERALLY AFTER BROADENING THERE WILL BE            SIGMA1
FEWER DATA POINTS IN THE RESONANCE REGION, BUT AT LOW ENERGY          SIGMA1
THERE MAY BE MORE POINTS, DUE TO THE 1/V LOW ENERGY EFFECT            SIGMA1
CREATED BY DOPPLER BROADENING.                                        SIGMA1
                                                                      SIGMA1
EFFECTIVE TEMERATURE INCREASE                                         SIGMA1
-----------------------------                                         SIGMA1
IF THE ORIGINAL DATA IS NOT AT ZERO KELVIN THE PROGRAM WILL           SIGMA1
BROADEN THE DATA BY THE EFFECTIVE TEMPERATURE DIFFENCE TO THE         SIGMA1
FINAL TEMPERATURE. IF THE DATA IS ALREADY AT A TEMPERATURE THAT       SIGMA1
IS HIGHER THAN THE FINAL TEMPERATURE DOPPLER BROADENING IS            SIGMA1
```

```
NATURALLY NOT PERFORMED AND THE TEMPERATURE IN THE SECTION IS LEFTSIGMA1
AT ITS ORIGINAL VALUE.                                          SIGMA1
                                                                SIGMA1
MULTIPLE FINAL TEMPERATURES                                     SIGMA1
---------------------------                                     SIGMA1
THE PRESENT VERSION ONLY DOPPLER BROADENS TO ONE FINAL TEMPERATURESIGMA1
(IF THERE IS SUFFICIENT INTEREST EXPRESSED BY USERS FUTURE      SIGMA1
VERSION MAY BROADEN TO MULTIPLE TEMPERATURES. PLEASE            SIGMA1
CONTACT THE AUTHOR IF YOU ARE INTERESTED IN A MULTIPLE          SIGMA1
TEMPERATURE OPTION).                                            SIGMA1
                                                                SIGMA1
PROGRAM OPERATION                                               SIGMA1
-----------------                                               SIGMA1
EACH SECTION OF FILE 3 DATA IS CONSIDERED SEPERATELY. THE DATA  SIGMA1
IS READ AND DOPPLER BROADENED A PAGE AT A TIME (ONE PAGE IS     SIGMA1
60000 DATA POINTS). UP TO THREE PAGES OF DATA MAY BE IN THE CORE SIGMA1
AT ANY GIVEN TIME, THE PAGE BEING BROADENED, THE PAGE BELOW IT  SIGMA1
IN ENERGY AND THE PAGE ABOVE IT IN ENERGY. AFTER A PAGE HAS BEEN SIGMA1
BROADENED IT IS THINNED, IF THE ENTIRE SECTION CONTAINS ONLY    SIGMA1
ONE PAGE OR LESS, IT WILL STILL BE CORE RESIDENT AND WILL BE    SIGMA1
WRITTEN DIRECTLY FROM CORE TO THE OUTPUT TAPE. IF THE BROADENED, SIGMA1
THINNED SECTION IS LARGER THAN A PAGE, AFTER A PAGE HAS BEEN    SIGMA1
BROADENED AND THINNED IT IS WRITTEN TO A SCRATCH FILE. AFTER THE SIGMA1
ENTIRE SECTION HAS BEEN BROADENED AND THINNED THE DATA IS READ  SIGMA1
FROM SCRATCH TO CORE, ONE PAGE AT A TIME, THE OUTPUT TO THE OUTPUTSIGMA1
TAPE.                                                           SIGMA1
                                                                SIGMA1
ALLOWABLE ERROR                                                 SIGMA1
---------------                                                 SIGMA1
AFTER DOPPLER BROADENING THE CROSS SECTION IN THE RESONANCE REGIONSIGMA1
WILL GENERALLY BE MUCH SMOOTHER THAN THE UNBROADENED DATA AND CAN SIGMA1
BE REPRESENTED TO THE SAME ACCURACY BY A SMALLER NUMBER OF ENERGY SIGMA1
POINTS. THEREFORE AFTER DOPPLER BROADENING THE DATA CAN BE THINNEDSIGMA1
WITH ESSENTIALLY NO LOSE OF INFORMATION.                        SIGMA1
                                                                SIGMA1
THE ALLOWABLE ERROR MAY BE ENERGY INDEPENDENT (CONSTANT) OR ENERGYSIGMA1
DEPENDENT. THE ALLOWABLE ERROR IS DESCRIBED BY A TABULATED      SIGMA1
FUNCTION OF UP TO 20 (ENERGY,ERROR) PAIRS AND LINEAR INTERPOLATIONSIGMA1
BETWEEN TABULATED POINTS. IF ONLY ONE TABULATED POINT IS GIVEN THESIGMA1
ERROR WILL BE CONSIDERED CONSTANT OVER THE ENTIRE ENERGY RANGE. SIGMA1
WITH THIS ENERGY DEPENDENT ERROR ONE MAY OPTIMIZE THE OUTPUT FOR SIGMA1
ANY GIVEN APPLICATION BY USING A SMALL ERROR IN THE ENERGY RANGE SIGMA1
OF INTEREST AND A LESS STRINGENT ERROR IN OTHER ENERGY RANGES.  SIGMA1
                                                                SIGMA1
INPUT FILES                                                     SIGMA1
-----------                                                     SIGMA1
UNIT  DESCRIPTION                                               SIGMA1
----  -----------                                               SIGMA1
   2  INPUT CARDS (BCD - 80 CHARACTERS/RECORD)                  SIGMA1
  10  ORIGINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)         SIGMA1
                                                                SIGMA1
OUTPUT FILES                                                    SIGMA1
------------                                                    SIGMA1
UNIT  DESCRIPTION                                               SIGMA1
----  -----------                                               SIGMA1
   3  OUTPUT REPORT (BCD - 120 CHARACTERS/RECORD)               SIGMA1
  11  FINAL ENDF/B DATA (BCD - 80 CHARACTERS/RECORD)            SIGMA1
                                                                SIGMA1
SCRATCH FILES                                                   SIGMA1
-------------                                                   SIGMA1
UNIT  DESCRIPTION                                               SIGMA1
----  -----------                                               SIGMA1
  12  SCRATCH FILE FOR BROADENED DATA                           SIGMA1
      (BINARY - 180000 WORDS/RECORD - DOUBLE PRECISION/         SIGMA1
                 42000 WORDS/RECORD - SINLGE PRECISION)         SIGMA1
                                                                SIGMA1
OPTIONAL STANDARD FILE NAMES (SEE SUBROUTINE FILEIO)            SIGMA1
----------------------------------------------------            SIGMA1
UNIT  FILE NAME                                                 SIGMA1
----  ----------                                                SIGMA1
  2   SIGMA1.INP                                                SIGMA1
```

```
  3   SIGMA1.LST                                                    SIGMA1
 10   ENDFB.IN                                                      SIGMA1
 11   ENDFB.OUT                                                     SIGMA1
 12   (SCRATCH)                                                     SIGMA1
                                                                    SIGMA1
INPUT CARDS                                                         SIGMA1
-----------                                                         SIGMA1
CARD  COLS.  DESCRIPTION                                            SIGMA1
----  -----  -----------                                            SIGMA1
   1   1-11  SELECTION CRITERIA (0=MAT, 1=ZA)                       SIGMA1
        12-22  MONITOR MODE SELECTOR                                SIGMA1
               = 0 - NORMAL OPERATION                               SIGMA1
               = 1 - MONITOR PROGRESS OF DOPPLER BROADENING OF DATA.SIGMA1
                     EACH TIME A PAGE OF DATA POINTS IS WRITTEN TO  SIGMA1
                     THE SCRATCH FILE PRINT OUT THE TOTAL NUMBER OF SIGMA1
                     POINTS ON SCRATCH AND THE LOWER AND UPPER      SIGMA1
                     ENERGY LIMITS OF THE PAGE (THIS OPTION MAY BE  SIGMA1
                     USED IN ORDER TO MONITOR THE EXECUTION SPEED   SIGMA1
                     OF LONG RUNNING JOBS).                         SIGMA1
        23-33  KELVIN TEMPERATURE                                   SIGMA1
        34-44  MINIMUM CROSS SECTION OF INTEREST                     SIGMA1
               (DEFAULT VALUE = 1.0E-10 BARNS).                     SIGMA1
        45-55  NEGATIVE CROSS SECTION TREATMENT                     SIGMA1
               = 0 - O.K.                                           SIGMA1
               = 1 - SET = 0                                        SIGMA1
        56-66  UNRESOLVED RESONANCE REGION TREATMENT                 SIGMA1
               = 0 - COPY (NO BROADENING)                           SIGMA1
               = 1 - IGNORE (BROADEN)                               SIGMA1
   2   1-72  ENDF/B INPUT DATA FILENAME                             SIGMA1
               (STANDARD OPTION = ENDFB.IN)                         SIGMA1
   3   1-72  ENDF/B OUTPUT DATA FILENAME                            SIGMA1
               (STANDARD OPTION = ENDFB.OUT)                        SIGMA1
 4-N   1-11  LOWER MAT OR ZA LIMIT                                  SIGMA1
        12-22  UPPER MAT OR ZA LIMIT                                SIGMA1
               UP TO 100 MAT OR ZA RANGES MAY BE SPECIFIED, ONE     SIGMA1
               RANGE PER CARD. THE LIST OF RANGES IS TERMINATED BY  SIGMA1
               A BLANK CARD. IF THE UPPER LIMIT IS LESS THAN THE    SIGMA1
               LOWER LIMIT THE UPPER LIMIT WILL BE SET EQUAL TO THE SIGMA1
               LOWER LIMIT. IF THE FIRST REQUEST CARD IS BLANK IT   SIGMA1
               WILL TERMINATE THE LIST OF REQUESTS AND CAUSE ALL    SIGMA1
               DATA TO BE RETRIEVED (SEE EXAMPLE INPUT).            SIGMA1
 VARY  1-11  ENERGY FOR ERROR LAW                                   SIGMA1
        12-22  ERROR FOR ERROR LAW                                  SIGMA1
               THE ACCEPTABLE LINEARIZING ERROR CAN BE GIVEN AS AN  SIGMA1
               ENERGY DEPENDENT FUNCTION SPECIFIED BY UP TO 20      SIGMA1
               (ENERGY,ERROR) PAIRS AND LINEAR INTERPOLATION        SIGMA1
               TABULATE POINTS. ENERGIES MUST BE IN ASCENDING ORDER.SIGMA1
               THE ERROR LAW IS TERMINATED BY A BLANK CARD. IF THE  SIGMA1
               FIRST ERROR LAW CARD IS BLANK IT WILL TERMINATE THE  SIGMA1
               ERROR LAW AND THE ERROR WILL BE TREATED AS ENERGY    SIGMA1
               INDEPENDENT, EQUAL TO ZERO, WHICH INDICATES THAT THE SIGMA1
               BROADENED DATA SHOULD NOT BE THINNED.                SIGMA1
                                                                    SIGMA1
EXAMPLE INPUT NO. 1                                                 SIGMA1
------------------                                                  SIGMA1
BROADEN ALL URANIUM ISOTOPES AND THORIUM-232 TO 300 KELVIN. FROM    SIGMA1
0 TO 100 EV THIN OUTPUT DATA TO 0.1 PER-CENT ACCURACY. FROM 100 EV  SIGMA1
TO 1 KEV VARY THE ERROR BETWEEN 0.1 AND 1 PER-CENT. ABOVE 1 KEV     SIGMA1
USE 1 PER-CENT ACCURACY.                                            SIGMA1
                                                                    SIGMA1
EXPLICITLY SPECIFY THE STANDARD FILENAMES.                          SIGMA1
                                                                    SIGMA1
THE FOLLOWING 11 CARDS ARE REQUIRED                                 SIGMA1
                                                                    SIGMA1
     1          0 3.00000+ 2                                        SIGMA1
ENDFB.IN                                                            SIGMA1
ENDFB.OUT                                                           SIGMA1
 92000      92999                                                   SIGMA1
 90232               (UPPER LIMIT WILL AUTOMATICALLY BE DEFINED)    SIGMA1
                     (BLANK CARD INDICATES END OF REQUEST LIST)     SIGMA1
0.00000+ 0 1.00000-03                                               SIGMA1
```

```
1.00000+ 2 1.00000-03                                                   SIGMA1
1.00000+ 3 1.00000-02                                                   SIGMA1
1.00000+ 9 1.00000-02                                                   SIGMA1
                        (BLANK CARD INDICATES END OF ERROR LAW)         SIGMA1
                                                                        SIGMA1
    EXAMPLE INPUT NO. 2                                                 SIGMA1
    -------------------                                                 SIGMA1
    BROADEN ALL DATA TO 300 KELVIN AND DO NOT THIN THE BROADEN DATA.    SIGMA1
    ALL OF THE STANDARD OPTION MAY BE INVOKED MERELY BY SPECIFYING      SIGMA1
    THE KELVIN TEMPERATURE ON THE FIRST CARD. ALL OTHER FIELDS MAY      SIGMA1
    BE LEFT BLANK.                                                      SIGMA1
                                                                        SIGMA1
    LEAVE THE DEFINITION OF THE FILENAMES BLANK - THE PROGRAM WILL      SIGMA1
    THEN USE STANDARD FILENAMES.                                        SIGMA1
                                                                        SIGMA1
    THE FOLLOWING 5 CARDS ARE REQUIRED                                  SIGMA1
                                                                        SIGMA1
                      3.00000+ 2                                        SIGMA1
                      (USE STANDARD FILENAME = ENDFB.IN)                SIGMA1
                      (USE STANDARD FILENAME = ENDFB.OUT)               SIGMA1
                      (RETRIEVE ALL DATA, TERMINATE REQUEST LIST)       SIGMA1
                      (0.0 ALLOWABLE ERROR, TERMINATE ERROR LAW)        SIGMA1
                                                                        SIGMA1
    EXAMPLE INPUT NO. 3                                                 SIGMA1
    -------------------                                                 SIGMA1
    THE SAME AS ABOVE, ONLY DEFINE THE MINIMUM CROSS SECTION OF         SIGMA1
    INTEREST TO BE 1.0E-30 BARNS (INSTEAD OF THE DEFAULT VALUE OF       SIGMA1
    1.0E-10).                                                           SIGMA1
                                                                        SIGMA1
    READ ENDF/B DATA FROM \ENDFB6\RECENT\ZA092238 AND WRITE ENDF/B      SIGMA1
    DATA TO \ENDFB\SIGMA1\ZA092238                                      SIGMA1
                                                                        SIGMA1
    THE FOLLOWING 5 CARDS ARE REQUIRED                                  SIGMA1
                                                                        SIGMA1
                      3.00000+ 2 1.00000-30                             SIGMA1
\ENDFB6\RECENT\ZA092238                                                 SIGMA1
\ENDFB6\SIGMA1\ZA092238                                                 SIGMA1
                      (RETRIEVE ALL DATA, TERMINATE REQUEST LIST)       SIGMA1
                      (0.0 ALLOWABLE ERROR, TERMINATE ERROR LAW)        SIGMA1
                                                                        SIGMA1
========================================================================SIGMA1
```