LA-6629-MS

Informal Report

UC-25

Issued: December 1976

Code Package for Calculation of Damage Effects of Medium-Energy Protons in Metal Targets

by

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This work was supported by the US Energy Research and Development Administration, Division of Physical Research.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$3.50 Microfiche \$3.00

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CODE PACKAGE FOR CALCULATION OF DAMAGE EFFECTS
OF MEDIUM-ENERGY PROTONS IN METAL TARGETS

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ABSTRACT

A program package has been developed to calculate radiation damage effects produced in a metal target by protons in the 100-MeV to 3.5-GeV energy range. This package contains a detailed description of the control cards and data cards required to use the code package.

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I. INTRODUCTION

A program package designed to calculate damage effects of medium-energy protons in metals has been developed and written to PHOTOSTORE with general read access. The present write-up is intended to describe the control cards and data cards required to use the package; and effort has been made to reduce these to the minimum possible. In addition, an attempt has been made to make the instructions detailed enough so that experience with complex computer codes is not required to follow them. No description is given here of the physical theories underlying the calculation. For these, one may refer to Ref. 1 and to papers and reports to be issued hereafter.

The program package is capable of calculating damage energy, recoil energy spectra, impurity deposition, and heating (among other things) for metal targets ranging in thickness from a few hundredths of a centimeter to a few centimeters which have great enough lateral extent so that they may be considered infinite in lateral directions--i.e., only coordinate dependence parallel to the beam is considered. Because certain damage-related functions are calculated for average values of the charge and mass numbers of the target nuclei, the results obtained are most accurate for target materials which are isotopic mixtures of a single element, or alloys containing a fairly narrow range of charge and mass numbers. Qualitatively useful results for the damage energy might be obtained for alloys/compounds with a fairly wide range of charge and mass numbers, however, and impurity production cross sections would be as good for this case as for that of a single element.

It is difficult to estimate the accuracy of the results of the calculation even in the most favorable cases--partly because of uncertainties in the best

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definition of the damage energy, and partly because of inaccuracies of results from the part of the code which calculates nuclear interactions. However, for reasonable statistics (see below) values of integrated quantities (total damage energy cross section, total spallation nucleus production cross section, etc.) and of production cross sections for neutrons and hydrogen isotopes are probably accurate to within a factor of two for single-element targets with average mass numbers above 40--and are likely to be significantly more accurate than this. The production and damage energy cross sections for individual spallation nuclei may be in error by a factor two or more in either direction, and those for the helium isotopes are likely to be low by a factor two or more. The accuracy of the calculation decreases as the average mass number does, and results become unreliable near ^{12}C .

The program package consists of three codes which are run consecutively, with intercode communication by means of disk files. The first program, START, calculates damage energy functions for spallation nuclei and light nuclei in the target material of interest. The second program, NMTC,² is an ORNL-produced, LASL-modified code which calculates the nuclear interactions produced by the protons in the target material. For its application in the present context one subroutine, ANALYZ, has been almost completely rewritten so as to record information of radiation damage relevance as it is generated by the remainder of the code. (The usual version of ANALYZ simply writes information to tape for later analysis.) The final code, DMGANAL, performs analysis of the information generated by NMTC and produces printed, film, and punched-card output to describe the results obtained. The code NMTC is on a permfile currently maintained by Philip A. Seeger of P-11. The remainder of the required programs, etc., are on a PHOTOSTORE fileset DAMAGE which contains the following five files:

1. Control cards.
2. Program START in UPDATE form.
3. Data cards which are the same for all NMTC runs in the present application.
4. UPDATE directives for NMTC.
5. Program DMGANAL in UPDATE form.

II. PROGRAM INPUT

The program package is designed to execute on the LASI CROS CDC 7600s. The control card and data deck setup are shown below. It is important to note the following points. 1) The \$JOB card should contain the LCM request LC=409000 and the recovery specification RC=0. Because the computation time required for a single target is perhaps thirty minutes to two hours, depending on the choice of various parameters, provision has been made to restart the calculation with only a small amount of recomputation (of order 2-3 minutes) in the event of a machine crash after the completion of program START but before the completion of the entire job. This restart capability can only be used with the specification RC=0 on the job card. 2) There must not be a \$FM. card between the data deck and the *IDENT DUM card following it.

```
$JOB(NAME=... ,LC=400000,RC=0)
$OPERM(FS=MACLIB2,0AC=ZD0,FSI=ZFSI)
$MARCO(MDF=MACLIB2,0AC=ZD0)
$PHOTOR(FS=DAMAGE,0AC=MPD0CAC,L0CAL=DMGDATA)
$OPEN(FS=NEWCCD,BUF=1000B)
```

```
$COPYF(I=DMGDATA,Ø=NEWCCD)
$REWIND(NEWCCD)
$SETQ(KEY=KCCF,Q=NEWCCD)
```

(Optional control cards discussed below.)

```
$FM.
*IDENT DUM
*CØMPILE START
$FM.
```

(Data deck to be described below.)

```
*IDENT DUM
*CØMPILE DMGANAL
$FM.
$EJ.
```

The optional control cards and the data deck are described below.

A. Optional Control Cards

1. At the beginning of the calculation two file sets are opened with TAPE disposition to serve (among other things) as backup storage for results as they are generated by NMTC so that economical restart of the calculation can be made in the event of machine crash prior to completion of the calculation. If the calculation terminates normally, the disposition of these filesets is changed to NONE. If for some reason it is desired to retain a tape record of the results obtained from NMTC, this may be accomplished by inserting the card

```
$ØPEN(FS=HSTP,ADISP=TAPE)
```

at the "optional control cards" position.

2. This writer has had bad experience with printer output from the CCF. Since it's rather frustrating to find missing columns and illegible pages in the printout from a \$600 run, the current program is set up to automatically generate a check-summed backup tape for the ØUT fileset. This tape can then be released if the initial printout is satisfactory, or used to print a readable copy on a CBT (using control cards specified below) if it is not. If for some reason the ØUT backup tape is considered unnecessary, it may be eliminated by inserting the control card

```
$ØPEN(FS=ØUTBKUP,ADISP=NØNE)
```

at the "optional control cards" position.

B. Data Cards

The data deck varies somewhat depending on whether the calculation being made is the first one for the target material, a repeat run (e.g., for a different target thickness or proton energy) for a target material considered previously, or a restart of a previous calculation which terminated prematurely because of machine crash or other reasons. The three cases are discussed separately below.

First Run

- Card 1. (A3,7X,A10,L10). (a) The word NEW should be punched in Cols. 1-3. (b) A ten-character descriptor for the material (e.g., ~~ALUMINUM~~) should be punched in Cols. 11-20. The word NEW in Cols. 1-3 will cause program START to punch a deck of cards containing damage parameters generated for the target material, and the use of this deck as part of the data deck on repeat runs for the material (see below) will reduce the computation time on these runs by approximately five minutes. If for some unusual reason it is desired to suppress this punched out on a first run, this may be accomplished by (c) punching a T in one of Cols. 21-30. Otherwise (and this would be the usual procedure) Cols. 21-30 should be left blank.
- Card 2. (2F10.0) (a) Columns 1-10 should contain a minimum energy, in eV, below which START will ignore the transfer of energy from above-cutoff protons (see Card 6) to target nuclei by Coulomb scattering. This minimum energy should in general be approximately equal to the displacement energy for a target atom, of order 25 eV for many metals. (b) Columns 11-20 should contain the minimum energy, in eV, to be used for the construction of the target nucleus recoil energy spectrum by DMGANAL. In general it would be reasonable to use the same value as for (a). If this energy is specified as less than that in (a) it is set equal to (a) for physical consistency. If it is specified as greater than 900 eV it is (somewhat arbitrarily) reduced to 900 eV for program technical reasons.
- Card 3. (8A10). Title Card. This card is used by NMTC for header information and may contain any identifying information or comments the user wishes.
- Card 4. (8A10). Title Card. Same comments as for Card 3.
- Card 5. (020). Twenty-digit octal number (i.e., no 8's or 9's), the first four digits of which should be zeros. This number is used by NMTC as the seed for its pseudo-random-number generator.
- Card 6. (3E10.4,3110). (a) The incident proton energy, in MeV, is punched in Cols. 1-10. (b) The cutoff energy (MeV) for protons, below which NMTC will cease transporting these particles,² should be punched in Cols. 11-20. A reasonable range is 15-20 MeV for this cutoff, and 20 MeV has been used in calculations to date by this writer. (c) A cutoff energy for neutrons should be punched in Cols. 21-30. Recommended is 15 MeV, as above this energy NMTC seems reasonably accurate and below this energy experimental data are available for many materials. (d) A one should be punched in Col. 40. (This is the number of different material regions in the target, which must be one to be treated sensibly by the non-NMTC part of the program package.) (e) and (f) The number of incident protons in one "batch" should be punched in Cols. 41-50, and the number of batches in Cols. 51-60. The total number of protons incident on the target in the NMTC calculation is the product of these two numbers. There are RMS variations of several key quantities over the various batches calculated in the program, to yield information about the degree of "convergence" of the Monte Carlo results of NMTC, so use of several batches is desirable. Twenty batches (20 punched in Cols. 59-60) of 20 000 protons each (20000 punched in Cols. 46-50), for a total of 400 000 protons, were found to yield integrated cross sections with a statistical fluctuation of 3% or less for 800 MeV protons incident on a 1-cm-thick copper target.

Card 7. (10X,110). The number of distinct nuclear species (distinct pairs of A and Z values) present in the target material should be punched in Cols. 11-20 (e.g., for natural copper, with isotopes ^{63}Cu and ^{65}Cu present, a 2 would be punched in Col. 20).

Cards 8A,B,... Each (3E10.4). One card for each nuclear species indicated on Card 7 (e.g., two cards for natural copper). (a) The charge number of the nuclear species (e.g., 29. for copper) should be punched in Cols. 1-10. (b) The mass number of the nuclear species (e.g., 63. for ^{63}Cu) is punched in Cols. 11-20. (c) The number density of the nuclear species in the target, in units 10^{24} nuclei/cm³ (e.g., 5.890E-2 for ^{63}Cu), is punched in Cols. 21-30.

Card 9. (E10.5,15). (a) The thickness of the target in centimeters is punched in Cols. 1-10. (b) A 1 must be punched in Col. 15. (This last is required for NMTC to identify the material region for which the thickness is being specified.)

Card 10. (L10). A blank card. (By punching a T in one of Cols. 1-10 and adding an additional data card one could generate information about the neutron angular distribution. However, this information is of no great interest in the present context and the option will not be described here. For most practical purposes the neutron angular distribution may be considered isotropic in the laboratory frame.)

As stated earlier, the above data deck should be followed immediately (no intervening \$FM. card) by *IDENT DUM in the program deck.

As mentioned above, the NEW in Cols. 1-3 on Card 1 will (unless suppressed by a T in Cols. 21-30) cause START to punch a deck of cards containing most of the damage energy information generated by this program. A header card for the deck and Cols. 1-10 of each subsequent card in the deck will contain the ten-character identifier for the target material specified in Cols. 11-20 of Data Card 1. In addition, the header card specifies the number of cards following it in the deck which contain the damage energy data, and each of these cards is serially numbered in Cols. 78-80. When this punched deck is used as input for a repeat run (as described below) the header card should be left in the deck. The number of cards punched by START varies with the maximum target mass number, but is never greater than 261 cards (including the header card). Program DMGANAL also produces punched output (described later), and this output should be separated from the deck and not used as part of the data deck for repeat runs.

Repeat Run

The damage energy parameters determined by START depend only on the nuclear species present in the target material and on their number densities, not on the target thickness or the incident proton energy. Thus, if a subsequent damage calculation is made with changed values for these two last parameters (or, for some reason, with the original parameters), the damage parameter deck punched by START in the original run can be used to eliminate recalculation of these parameters and reduce computation time by four to seven minutes. For this purpose only two changes need be made in the data deck described under "First Run."

1. OLD (rather than NEW) should be punched in the first three columns of Card 1. (The ten-character material identification in Cols. 11-20 remains as before.) This causes START to expect to read the damage parameters from input and suppresses their calculation, punching, and printing. Any T or F entry in Cols. 21-30 of Card 1 is now ignored.

2. The deck of damage parameters punched in the initial run for this target material, including the header card, should be placed after the Card 10 described under "First Run."

In addition, of course, changes of parameters such as target thickness, proton energy, cutoff energy for target nucleus recoils due to above-cutoff proton Coulomb scattering, etc., may be made if desired.

Restart from Machine Crash

After calculating results from each 1000 incident protons NMTC prints time elapsed since beginning of program execution (including all compilation and loading to date and execution of START) and other information. It also prints a message at the end of each batch, indicating in particular the number of the batch just completed and the random number existing at the end of the batch. It then makes a call to ANALYZ, which (among other things) writes to disk the pertinent damage information generated up to that point in the execution of NMTC. This information is written to file set SAVE at the end of odd-numbered batches and to file set HSTP at the end of even-numbered batches, so that in the event of a machine crash at any time in the execution of NMTC one is reasonably sure (except in those crashes where the machine also clears the disk!) of preserving all the information generated by NMTC except at most that in the most recently calculated batch. In the event of a machine crash in execution of NMTC or DMGANAL a restart with minimal recomputation may be carried out as follows. First determine from the NMTC printout for the run that crashed what the last completed batch was. This will be the batch for which the last end-of-batch message was printed and at least one subsequent end-of-1000-particle-group message was printed. (If no end-of-1000-particle-group message was printed between the end-of-batch message and the crash, one cannot be certain the disk write for that batch was completed before the crash occurred.) If the batch number for this last batch is odd, the XX tape generated from fileset SAVE is used as input for the restart. If the last batch number is even, the XX tape generated from fileset HSTP is used as input for the restart. The tape number for the appropriate fileset can be determined from the Job Day File for the aborted job. One may then restart using the control card-data deck setup described under "Repeat Run" (the damage parameter deck will be available, since START will have executed to execution) with the three following modifications.

1. Immediately after the \$PHOTØR(FS=DAMAGE,ØAC=MPDØCAC,LØCAL=DMGDATA) control card insert the control card

\$GETMT(FS=SAVE,MT=XX____)

where the six-digit tape number determined as described above is inserted after XX.

2. Add two parameters to Card 1 in the data deck, which now is to be thought of as having the format (A3,7X,A10,L1Ø,L1Ø,L1Ø). (a) In one of Cols. 31-40 a T should be punched to inform NMTC that this is a restart of a previously begun calculation. (b) In Cols. 41-50 should be punched the number of the last completed batch in the previous calculation, determined in the manner described above. As in the "Repeat Run" case, ØLD will be punched in Cols. 1-3 and the ten-character material identifier in Cols. 11-20. It is assumed Cols. 21-30 are left blank, since they are ignored anyway unless NEW appears in Cols. 1-3.

3. The random number on Card 5 will now be the random number shown on the NMTC printout for the end of the last completed batch.

If a first-run calculation aborts due to machine crash after the damage parameter deck has been punched but before the first batch of collisions has been completed by NMTC, the job should be run again in the "Repeat Run" form. Otherwise, jobs which abort due to machine crash before NMTC has calculated the first batch of collisions must be rerun in their entirety.

There are two subroutines in program START, both connected with the calculation of damage energy parameters for the hydrogen and helium isotopes, which have the capability of aborting the job. One of these is a Newton's-method routine for locating the zero of a function, which returns with an error message if the routine has not converged to the specified accuracy within a certain number of iterations. The other is a linear system solver which can return with an error message under similar circumstances. In either case, an appropriate error message is printed, the damage energy parameters calculated for the heavy spallation nuclei are printed and punched, and the job is then aborted. The damage parameter deck punched in this case will not contain the parameters for the hydrogen and helium isotopes and will be ten cards shorter than indicated on the header card. The writer has never experienced difficulty with either of these subroutines and knows of no reason why difficulty should ever occur. If a problem does arise there is no "fix." If a recheck of the control card and data card deck does not reveal any mistake, then the user who encounters a job abort at either of these points should contact the writer.

III. PROGRAM OUTPUT

Output produced by the program package is discussed below for individual programs in the sequence.

A. Program START

The punched output generated by START on a "First Run" (NEW on Card 1) has already been discussed. On a first run START will print a list of total, recoil energy, and damage energy cross sections at selected energies for above-cutoff protons in the target material, and will also print a list of the damage energy parameters which are punched on cards. On a repeat run (OLD on Card 1) START produces no punched, printed, or other output.

B. Program NMTC

NMTC prints a page and a half summarizing input data and pertinent parameters calculated therefrom, the end-of-1000-particle and end-of-batch messages discussed earlier, and a summary at program completion. For the meaning of information appearing in the summary see Ref. 2.

C. Program DMGANAL

DMGANAL prints production cross sections, damage energy cross sections, and recoil energy information both collectively and for individual nuclei-particles produced in the nuclear interactions. It also prints a great deal of other information concerning electronic energy loss in the target, particle decay and escape from the target, depth distributions for various quantities, etc. Graphs and three-dimensional-perspective plots of many of the cross sections, energy spectra, and depth distributions are produced on film. Finally, the energy spectrum for below-cutoff neutrons is punched on cards. These cards

may be used as input to some external program such as DØN³ (for which use, in fact, the cards are formatted) to obtain information which can be used in the manner described in Ref. 1 to determine damage energy effects, etc., of below-cutoff neutrons. Their contribution is relatively small for active target volumes no larger than approximately 1 cm on a side, and so can be neglected in many cases.

It is seen from the above that every run of the program package which executes to completion will generate three types of output: printed, film, and punched card.

If the printed output from a run is of poor quality and you were wise enough not to suppress generation of the backup tape for the ØUT fileset, another copy of the printed output can be produced (preferably on a CBT printer) as follows. The backup fileset for ØUT is (naturally enough) ØUTBKUP. Determine from the Job Day File the XX tape number to which this fileset was written. The following control card deck will produce a new printed copy of the ØUT file (but now named TEMPØUT) from this tape.

```
$JOB(NAME=...)
$LABEL(LB=RESTAGE)
$CREATE(FS=TEMP,PREMT=XX____)
    (The six-digit tape number determined from the Job Day File
    should be inserted after XX.)
$PARITY(FS=TEMP,TRUE=BAD)
$CREATE(FS=TEMPØUT,SCT=4000)
$CKSUM(I=TEMP,Ø=TEMPØUT)
$IF(FALSE=ØK)
$REWIND(FS=TEMPØUT)
$LABEL(LB=BAD)
$AFSREL(FS=TEMP)
$BACK(LB=RESTAGE)
$LABEL(LB=ØK)
$AFSREL(FS=TEMPØUT,ADISP=PRT)
$STØP.
$FM.
$EJ.
```

If no optional control cards are inserted in the control card deck, a job which executes to completion will generate one tape (from ØUTBKUP); and a job which aborts will generate one (from HSTP) or two (from HSTP and SAVE) tapes, depending on position in the job when abort occurs. As usual, if job submission is made from a CBT the operator of the machine to which the job is assigned should be notified by phone of the name and group number of the person to whom any tapes generated are to be assigned.

IV. PROGRAM TIMING AND STATISTICS

In calculations made for copper, program START executed in 6 minutes 15 seconds on a "First Run" and in about 45 seconds on a "Repeat Run." NMTC required about 18 minutes 15 seconds to calculate damage effects due to 240 000 800-MeV protons (20 batches of 12 000 protons each) incident on a 1-cm-thick copper target. DMGANAL performed the analysis of these results for copper and produced the printed, punched-card, and film output in about 1 minute 20 seconds.

All these execution times will vary with average target A value, being somewhat larger for larger A. In addition, for a given target material NMTC execution time will vary approximately linearly with target thickness and with total number of protons incident on the target. Finally, execution time for START will vary with choice of the cutoff recoil energy considered in proton Coulomb scattering, being lower for higher recoil energy cutoff.

NMTC checks time remaining after each 1000-proton group is completed and terminates execution when the remaining time is too small to calculate another group. In this case, the last proton batch calculated will not have the number of particles specified on Card 6 and/or the total number of batches specified on Card 6 will not be run. When this occurs ANALYZ will not write the results at the end of the final, incomplete batch to disk and will abort the job after NMTC has written its end-of-program summary. This will automatically result in files SAVE and HSTP being written to tape. Just as in the case of a machine crash, the tape written from SAVE will contain information from the last complete odd-numbered batch and the tape written from HSTP will contain information from the last complete even-numbered batch. The appropriate one of these tapes should be used to restart the calculation in the same fashion as for job abort due to machine crash.

Since NMTC uses Monte Carlo computational methods, sizeable statistical fluctuations occur in computed quantities unless an adequate number of nuclear interactions have occurred in the calculation. It was found that 400 000 800-MeV protons incident on a 1-cm-thick copper target produced about 35 000 nuclear interactions and yielded a statistical uncertainty in "integrated" and light-nucleus cross sections of about 3%. Individual spallation nucleus cross sections have larger uncertainties, particularly those with A and Z values differing significantly from target A and Z values.

It should be noted that the restart feature can also be used to improve statistics by using the optional \$OPEN(FS=HSTP,ADISP=TAPE) card on the first run. If it is then found after this run that the statistics of the results obtained were not as good as desired, a restart as described under "Restart from Machine Crash" can be made. In this case, however, restart is always made from the tape generated from HSTP; the batch number in Cols. 41-50 of Card 1 should be the total number of batches calculated in the first run; the random number on Card 5 should be the final random number obtained from the first run; and the batch number specified in Cols. 51-60 of Card 6 should be increased to a new, larger number estimated as adequate to give the desired statistics. Other system parameters must not be changed.

V. FILE AND PROGRAM LISTINGS

Listings of the control card deck on file 1 of fileset DAMAGE and the data card deck on file 3 of fileset DAMAGE are given in Appendixes A and B, respectively. These files are both present in the fileset in the form of card images.

NMTC is a large code with several overlays. Part of the code is present on its permfile in UPDATE form, and part in the form of relocatable binary decks. File 4 of fileset DAMAGE is a card-image set of UPDATE directives for that part of NMTC which is in UPDATE form. These directives determine the set of subroutines of NMTC which are compiled, almost completely redefine subroutine ANALYZ, and make minor modifications in other programs and subroutines (correcting errors, changing program fileset specifications, making a few format modifications, altering the order of certain subroutine calls in order to implement

the restart feature, etc.). Listings of START, DMGANAL, and much of the updated version of that part of NMTC which is in UPDATE form can be obtained by using the sets of control cards described below. However, fair warning is given that START, DMGANAL, and the modified ANALYZ are poorly documented, and that ANALYZ and DMGANAL contain a large number of unpronounceable names for arrays whose significance will probably become apparent only after prolonged study.

The control card deck to list any of the three programs begins with the same four cards:

```
$JOB(NAME=...)
$PERM(FS=MACLIB2,ØAC=ZDØ,FSI=ZFSI)
$MACRØ(MDF=MACLIB2,ØAC=ZDØ)
$PHØTØR(FS=DAMAGE,ØAC=MPDØCAC,LØCAL=DMGDATA).
```

To list the various programs, the above four cards should be followed by those specified below.

A. For START:

```
$SKIPF(FS=DMGDATA)
$UPDATE(Q,P=DMGDATA,R=C)
$RUN(C=SR,I=CØMPILE)
$FM.
*IDENT DUM
*CØMPILE START
$EJ.
```

B. For NMTC:

```
$SKIPF(FS=DMGDATA,N=3)
$PERM(FS=NMTC,FSI=PFSI,ØAC=PDØ)
$UPDATE(F,P=NMTC,I=DMGDATA,L=Ø,R=C)
$RUN(C=SR,I=CØMPILE)
$FM.
$EJ.
```

C. For DMGANAL:

```
$SKIPF(FS=DMGDATA,N=4)
$UPDATE(Q,P=DMGDATA,R=C)
$RUN(C=SR,I=CØMPILE)
$FM.
*IDENT DUM
*CØMPILE DMGANAL
$EJ.
```

VI. FINAL COMMENT

All of the control and data card groupings and options described in this report have been tested by the writer and found to work correctly. Experience suggests this is no reason to think they will work correctly in the future. Program package users who experience problems are invited to contact the writer about their difficulties.

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APPENDIX A

CARD-IMAGE CONTROL CARDS - FILESET DAMAGE

The following is a list of the control cards present in card-image form in file 1 of fileset DAMAGE.

```
$UPDATE(Q,P=DMGDATA,L=0,R=C)
$RUN(C=NR,I=COMPILE)
$CLOSE(FS=COMPILE)
$OPEN(FS=HSTP,ADISP=TAPE)
$OPEN(FS=CINPUT,BUF=1000B)
$LDG(SETA=I,LC=100000,M=NONE)
$CLOSE(FS=BIN)
$OPEN(FS=INP,BUF=2000B)
$PERM(FS=NMTC,FSI=PFSI,AC=PD)
$UPDATE(F,P=NMTC,I=DMGDATA,L=0,R=C)
$RUN(C=NR,I=COMPILE)
$CLOSE(FS=COMPILE)
$COPYF(I=NMTC,Ø=BIN)
$COPYF(I=NMTC,Ø=BERTP)
$AFSREL(FS=NMTC)
$LOAD(SETA=I,M=NONE)
$NØGØ
$CLOSE(FS=BIN)
$REWIND(NMTC1 $ NMTC2 $ BERTP)
$OPEN(FS=SAVE,ADISP=TAPE)
$LDG(I=NMTC1,LC=100000,SETA=I,M=NONE)
$UPDATE(Q,P=DMGDATA,L=0,R=C)
$AFSREL(FS=DMGDATA)
$RUN(C=NR,I=COMPILE)
$CLOSE(FS=COMPILE)
$LDG(SETA=I,M=NONE)
$OPEN(FS=ØUTBKUP,ADISP=TAPE)
$REWIND(FS=ØUT)
```

```

$CKSUM(I=OUT,Ø=ØUTBKUP,TYPE=SUM)
$ØPEN(FS=HSTP,ADISP=NØNE)
$OPEN(FS=SAVE,ADISP=NONE)
$SETQ(KEY=KCCF,Q=CCD)
$FM.

```

APPENDIX B

CARD-IMAGE NMTC DATA CARDS - FILESET DAMAGE

The following is a description of NMTC data cards present in card-image form in file 3 of fileset DAMAGE. All columns are blank except those explicitly indicated to the contrary.

Card 1.	(a) Col. 30	1
	(b) Cols. 39-40	10
	(c) Col. 50	0
Card 2.	(a) Cols. 7-10	0.E0
	(b) Cols. 17-20	0.E0
	(c) Col. 30	1
	(d) Col. 40	1
	(e) Col. 50	1
	(f) Col. 60	0
Card 3.	blank	
Card 4.	Cols. 6-10	50.E0
Cards 5-7.	blank	
Card 8.	Cols. 1-4	\$FM.