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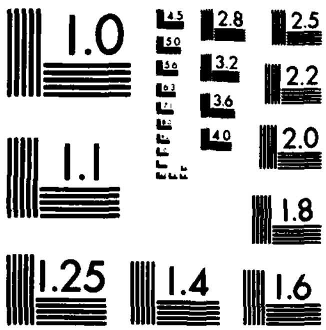
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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

MATERIALS RESEARCH LABORATORIES

MELBOURNE, VICTORIA

REPORT

MRL-R-925

SPEEDING UP THE HELP HYDRODYNAMIC CODE

David L. Smith

Approved for Public Release

MAY, 1984

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TITLE

SPEEDING UP THE HELP HYDRODYNAMIC CODE

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The Eulerian hydrodynamic code HELP has been employed at MRL for some years to model problems in warhead research. One disadvantage of HELP has been the long computer run-times associated with its use. This report describes a modification to the code which makes it run up to three times faster.

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C O N T E N T S

SPEEDING UP THE HELP HYDRODYNAMIC CODE

1. INTRODUCTION

The two-dimensional Eulerian hydrodynamic computer code HELP (Hydrodynamic ELastic Plastic) has been employed at the Materials Research Laboratories (MRL) for some years to model explosive-metal interactions in warhead research. HELP was developed in the US during the 1970's, and is well described in Reference [1]. The version of HELP in use at MRL [2] was obtained from the US Army Ballistic Research Laboratory through the auspices of TTCP.

HELP suffers the common disadvantage of Eulerian codes in that it demands long computer run-times to solve useful problems. At MRL, HELP has largely been run on a CDC-7600 computer on the CSIRONET network. For warhead problems such as shaped charge collapse, 3 to 4 hours CPU time on the 7600 would be required for a typical run. This is not only expensive but also inconvenient, as run-times of this length exceed user limits on CSIRONET, and can only be achieved by stopping and restarting at a later date.

With these factors in mind, it was decided to investigate the possibility of improving the efficiency of HELP, without changing its basic modus operandi. This report describes the analysis of the code's run-time performance, and presents a modification to HELP which increases its speed up to threefold.

2. ANALYSIS OF HELP PERFORMANCE

2.1 Run-time Profiles by Subroutine

The first approach to analysing the performance of HELP was to establish which of the subroutines were absorbing most of the computer time. This was achieved using the P-register sampling utilities (PREGON, PRLIST) available on the 7600 under the SCOPE operating system [3]. These utilities record the programme address under execution every 3.6 milliseconds, when the hardware clock interrupts the executing programme for system housekeeping. At the end of execution, these data are processed to build a statistical profile of programme addresses vs frequency. A loader map can then be used to associate these addresses with programme segments.

Two fairly typical problems previously run with HELP at MRL were chosen and re-run with P-register analysis. The first of these was a 1.5 inch diameter hemispherical shaped charge, given in Reference [2] as a sample problem for the BRL version of HELP. The complete input deck for this run is given in Appendix 1. (The input has been modified slightly from that in Reference [2], partly due to memory constraints, and partly to include the strength phase of HELP to assess its time consumption). Schematic illustrations for this problem at the beginning and end of the HELP run may be found in Figures 1 and 2 respectively. The second study chosen was a 38 mm shaped charge of the type used frequently in experimental studies at MRL [4]. The input deck for this run is given in Appendix 2, and illustrations are at Figures 3 and 4.

The profile analyses for these two jobs are presented in terms of the percentage of total CPU time taken by each subroutine. The hemisphere job, run 1.023, used 5720 seconds of 7600 time, and its analysis is shown in Table 1. The shaped charge job, run 50.0009, was stopped after 500 cycles and used 6829 seconds CPU time; its analysis is shown in Table 2.

The profiles reveal that in both runs the tracer moving subroutine MOVTCR accounted for the bulk of the run-time. This routine used 61.7% of the total time in the first run, and 68.8% in the second. Clearly a significant improvement to the overall performance of HELP could only be achieved by improving MOVTCR, and hence this subroutine was analysed in detail.

2.2 Analysis of Subroutine MOVTCR

Subroutine MOVTCR is called on every sub-cycle of HELP, to move the massless tracer particles which define material boundaries. MOVTCR also moves cell-centred passive tracers if these have been selected. Both types of tracer are moved in a pseudo - continuous local velocity field: the method is described in detail in Section 4.1.2 of Reference [1].

In order to establish exactly which segments of MOVTCR were consuming the computer time, a further P-register analysis run was performed. This run concentrated on the load addresses occupied by MOVTCR. A cross-referenced listing then enabled identfication of the offending code. It was found that over 95% of the subroutine's time was spent in one small inner loop. Appendix 3 contains a listing of MOVTCR: the loop referred to is DO 1200, between MOVTRC.48 and MOVTCR.52.

Understanding the function of this loop requires a little knowledge of the workings of HELP. Each material package is defined spatially by an ordered set of tracer particles which form the package boundaries. These tracers are also used by the code to "sense" whether material is entering or leaving a cell, and to define fractional cell areas across which such transport may occur. This is quite the most complicated logic in HELP. The logic requires that the "void package", present in nearly all HELP problems, have its own set of tracer particles. These tracers must be coincident with tracers from other material packages but are kept as an independent ordered set. When tracer particles for (non-void) materials are moved on each cycle or sub-cycle, the corresponding void tracer is found and moved identically. The function of the DO 1200 loop in MOVTCR is simply to find whether the tracer being considered has a corresponding void tracer which needs to be moved. Since most typical HELP runs involve in the order of 1000 tracers for each package, it is not surprising that this loop, being executed each sub-cycle in the order of 1,000,000 times, proved very time-consuming.

3. MODIFICATIONS TO MOVTCR

Since coincident tracers are moved identically, it is not necessary to check for these every cycle or sub-cycle, because they will remain associated. The only way this association could alter is when new tracers are added or existing ones removed. This can only happen when subroutine ADDTCR is called to interpolate new tracers because existing ones have become sparse, or when tracers are adjusted manually on restarts or automatically by VDCLOS, the void closing routine.

The solution was to associate each void package tracer with a corresponding material tracer and store this information at the time of problem set-up. Further checks then need only be made if tracers have been added or deleted.

To do this, a new subroutine TCRCHK was added to HELP. This subroutine checks each tracer of the void package to find a coincident material package tracer. A "pointer" array is filled so that each void tracer has a floating point number associated with it. The fractional part of this number contains the material package number, and the integer part the tracer number for the matching tracer. Subroutine MOVTCR now moves all non-void tracers first, and then moves void tracers according to the information encoded in this array. TCRCHK is called on problem initialisation and then only called again if ADDTCR adds new tracers, if VDCLOS removes tracers, or on problem restart. An UPDATE [5] correction run to incorporate these modifications, including the new routine TCRCHK, is given in Appendix 4.

Whilst it is not claimed that this solution is necessarily the most elegant, its attraction is that it makes no changes to the existing tracer particle logic in HELP and hence cannot have any unforeseen consequences. It should also substantially reduce run-times for all HELP simulations which include a void package.

4. RESULTS

The two test problems chosen in Section 2.1 were re-run with the modified version of HELP. Resultant outputs were found to be identical. For the hemisphere calculation, run-time was reduced from 5720 seconds to 2440 seconds (43%), and for the shaped charge calculation from 6829 seconds to 2386 seconds (35%). Tables 3 and 4 show subroutine profile analyses for these runs. For the hemisphere run subroutines MOVTCR and the new routine TCRCHK together accounted for 6.9% of the run-time, compared to the previous figures of 61.7%. For the shaped charge run the corresponding figures are 7.6% and 68.8%.

It seems reasonable to assume that for most applications of HELP, this modification will increase the code's speed by a factor of between two and three.

5. REFERENCES

1. HELP - A Multimaterial Eulerian Program in Two Space Dimensions and Time, L.J. Hageman et al, Systems, Science and Software. Final Report AFATL-TR-76-45, April 1976.

2. The BRL 7600 Version of the HELP Code. J. Lacetera et al, US Army Ballistic Research Laboratory, Technical Report ARBRL-TR-02209, January 1980.

3. SCOPE 2.1 Reference Manual, Revision 2, Control Data Corporation, Manual 60342600.

4. Fabrication and Performance Assessment of Shaped Charges. M.C. Chick and G.P. Briggs, Defence Standards Laboratories Report No. 546, June 1974.

5. UPDATE Reference Manual, Control Data Corporation, Manual 60449900 (UPDATE is a utility for maintaining large files).

TABLE 1

PROFILE ANALYSIS FOR RUN 1.023

RUN-TIME = 5720 seconds

(PERCENTAGES TO NEAREST 0.1%)

SUBROUTINE	% TIME	SUBROUTINE	% TIME
MAIN	0.0	NEWMIX	0.0
ADDTCR*	0.0	NEWRHO	0.0
CALFRC	0.0	PTSAV	0.1
CDT	2.8	REZONE	0.0
CMPRSN	0.0	RNDOFF	0.0
COMPRS	0.0	SETUP	0.0
DETIME	0.0	SETUPA	0.2
DMADJ	0.8	SPHASE	2.6
DMCALC	1.7	STRNG	0.1
EDIT	0.0	THETAS	0.1
ENCHK	3.3	TPHASE	11.1
ENDMV	0.0	TSETUP	0.0
EOUT	0.1	UVCALC	0.0
EQST	1.3	UVMOD	0.2
ERROR	0.0	VDCLOS	0.0
FILGRD	0.0	XY,Y,-PTOC	0.1
FLGSET	1.9	ADDENG	0.0
FRACS	1.9	UC	0.0
HPHASE	5.8	VC	0.0
INFACE	0.0	VOLFND	0.0
INPUT	0.0	WN	0.0
MAP	0.1	X,Y,-CTOP	0.0
MOVTCR	61.7	SYSTEM FUNCTIONS	3.4
NEWFLG	0.0		

* No tracers added in this run.

T A B L E 2

PROFILE ANALYSIS FOR RUN 50.0009

RUN-TIME = 6829 SECONDS

(PERCENTAGES TO NEAREST 0.1%)

SUBROUTINE	% TIME	SUBROUTINE	% TIME
MAIN	0.0	NEWMIX	0.0
ADDTCR	13.3	NEWRHO	0.0
CALFRC	0.0	PTSAV	0.2
CDT	1.3	REZONE	0.0
CMPRSN	0.0	RNDOFF	0.0
COMPRS	0.0	SETUP	0.0
DETIME	0.0	SETUPA	0.2
DMADJ	0.5	SPHASE*	0.0
DMCALC	1.3	STRNG*	0.0
EDIT	0.0	THETAS	0.3
ENCHCK	1.3	TPHASE	4.5
ENDMV	0.0	TSETUP	0.0
EOUT	0.0	UVCALC	0.1
EQST	0.6	UVMOD	0.0
ERROR	0.0	VDCLOS	0.0
FILGRD	0.0	X,Y,-PTOC	1.4
FLGSET	0.8	ADDENG	0.0
FRACS	1.8	UC	0.0
HPHASE	1.8	VC	0.0
INFACE	0.0	VOLFND	0.0
INPUT	0.0	WN	0.0
MAP	0.0	X,Y,-CTOP	0.0
MOVTCR	68.8	SYSTEM FUNCTIONS	1.3
NEWFLG	0.0		

* No strength phase in this run.

TABLE 3

PROFILE ANALYSIS FOR RUN 1.024

RUN-TIME = 2440 SECONDS

(PERCENTAGES TO NEAREST 0.1%)

SUBROUTINE	% TIME	SUBROUTINE	% TIME
MAIN	0.0	NEWMIX	0.0
ADDTCR*	0.0	NEWRHO	0.0
CALFRC	0.0	PTSAV	0.1
CDT	6.7	REZONE	0.0
CMPRSN	0.0	RNDOFF	0.0
COMPRS	0.0	SETUP	0.0
DETIME	0.0	SETUPA	0.4
DMADJ	2.0	SPHASE	6.3
DMCALC	4.5	STRNG	0.1
EDIT	0.1	THETAS	0.1
ENCHCK	9.1	TPHASE	26.7
ENDMV	0.0	TSETUP	0.0
EOUT	0.0	UVCALC	0.1
EQST	3.2	UVMOD	0.5
ERROR	0.0	VDCLOS	0.0
FILGRD	0.0	X,Y,-PTOC	1.7
FLGSET	4.4	ADDENG	0.0
FRACS	4.6	UC	0.0
HPHASE	13.8	VC	0.0
INFACE	0.0	VOLFND	0.0
INPUT	0.0	WN	0.0
MAP	0.2	X,Y,-CTOP	0.0
MOVTCR	6.8	TCRCHK	0.1
NEWFLG	0.1	SYSTEM FUNCTIONS	8.2

* No tracers added in this run

TABLE 4

PROFILE ANALYSIS FOR RUN 50.0010

RUN-TIME = 2386 SECONDS

(PERCENTAGES TO NEAREST 0.1%)

SUBROUTINE	% TIME	SUBROUTINE	% TIME
MAIN	0.0	NEWMIX	0.0
ADDTCR	39.7	NEWRHO	0.0
CALFRC	0.0	PTSAV	0.8
CDT	3.6	REZONE	0.0
CMPRSN	0.0	RNDOFF	0.0
COMPRS	0.0	SETUP	0.0
DETIME	0.0	SETUPA	0.6
DMADJ	1.3	SPHASE*	0.0
DMCALC	4.0	STRNG*	0.0
EDIT	0.1	THETAS	0.7
ENCHCK	4.4	TPHASE	13.2
ENDMV	0.0	TSETUP	0.0
EOUT	0.0	UVCALC	0.2
EQST	1.6	UVMOD	0.1
ERROR	0.0	VDCLOS	0.0
FILGRD	0.0	ADDENG	0.0
FRACS	5.4	UC	0.0
HPHASE	5.5	VC	0.0
INFACE	0.0	VOLFND	0.0
INPUT	0.0	WN	0.0
MAP	0.1	X,Y,-CTOP	0.0
MOVTCR	5.8	TCRCHK	1.8
NEWFLG	0.1	SYSTEM FUNCTIONS	4.0

* No strength phase in this run

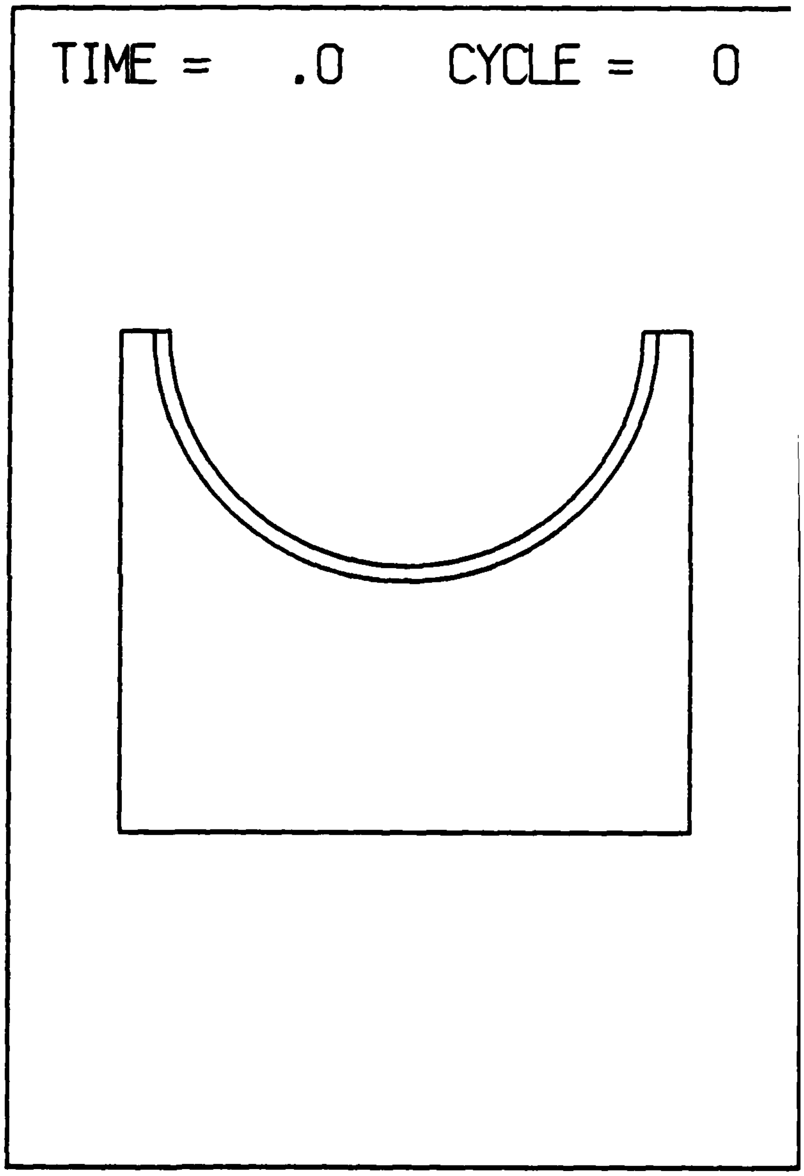

FIGURE 1

Hemispherical Shaped Charge

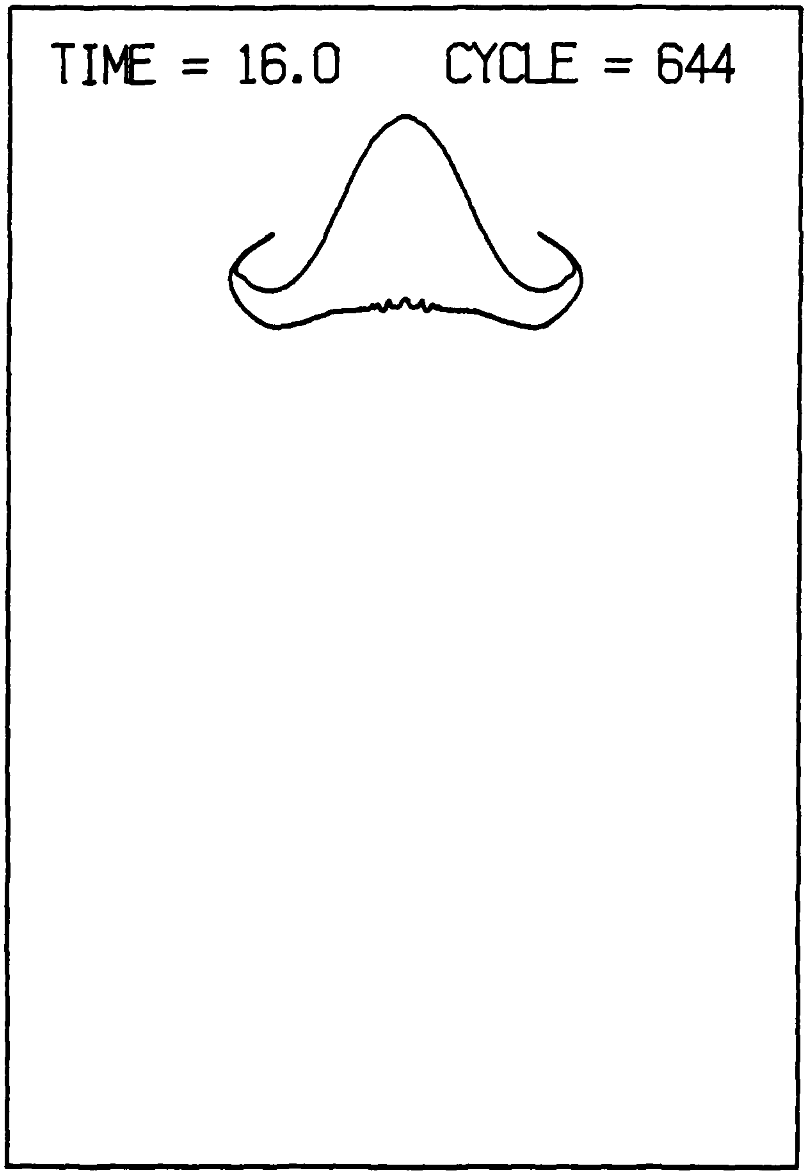

FIGURE 2

Hemispherical Shaped Charge

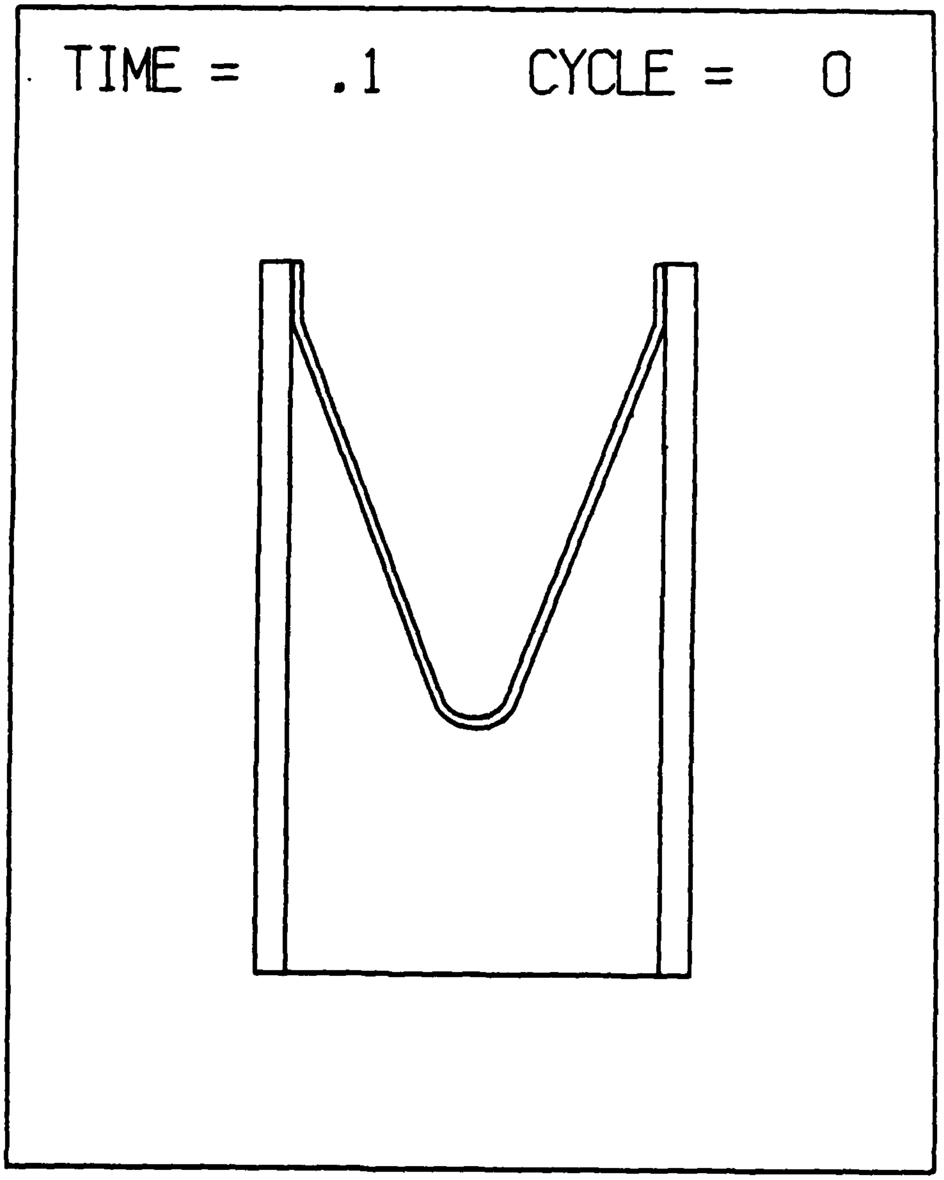

FIGURE 3

MRL Shaped Charge

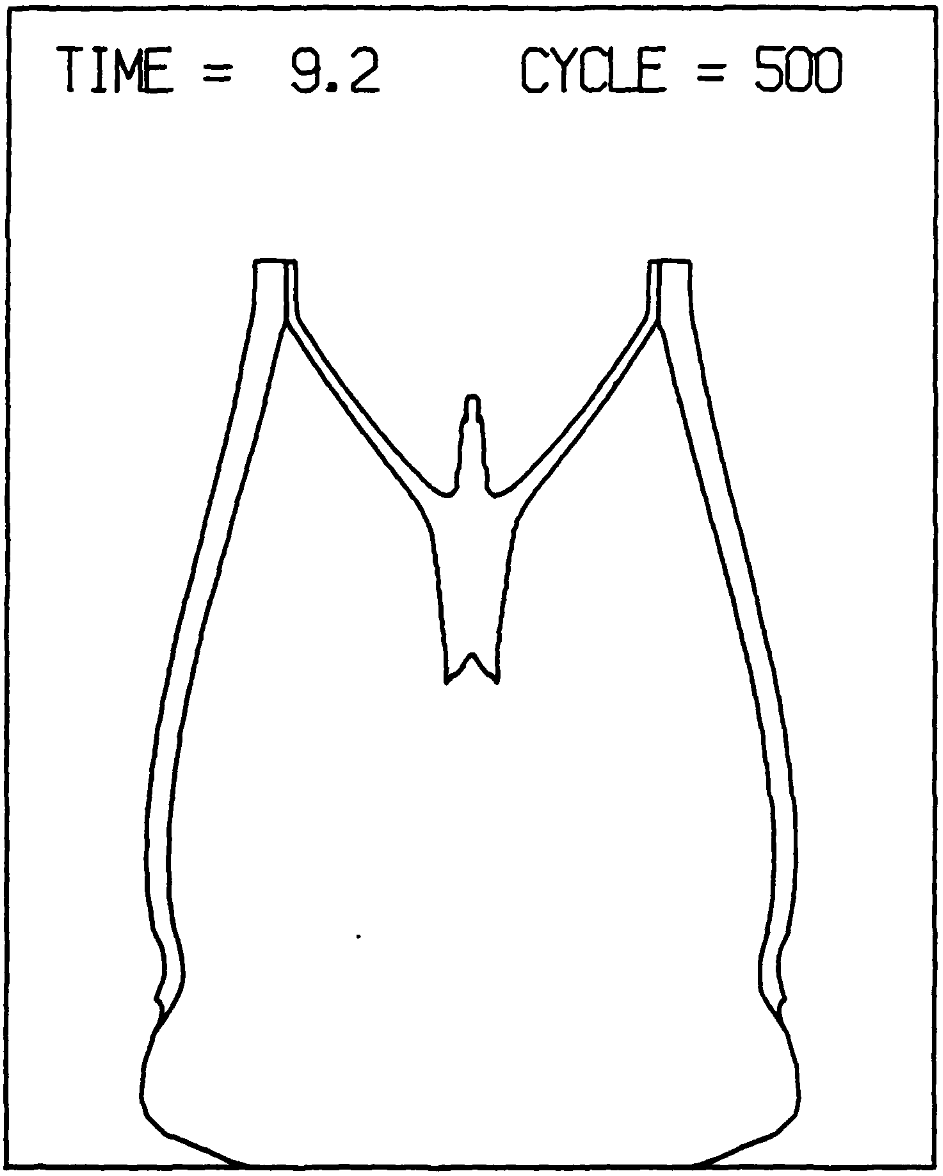

FIGURE 4

MRL Shaped Charge

APPENDIX 1

JOB TO RUN HEMISPHERICAL SHAPED CHARGE PROBLEM

```
SCRUN(P10,T20000,MS140000,ML600)
COMMENT. JOB TO RUN PROBLEM 1.023
COMMENT.  SAMPLE PROBLEM OF HEMISPHERE
LIMIT(0)
GETSET(DFC4405)
REQUEST(TAPE1,*PF,SN=DFC4405)
REQUEST(TAPE7,*PF,SN=DFC4405)
REQUEST(TAPE20,*PF,SN=DFC4405)
ATTACH,LGO,$LGO FOR MRLHLP20$,SN=DFC4405,ID=DFCDLS.
MAP(PART)
PREGON(FWA=0,LWA=140000)
LGO(PL=200000)
EXIT(U)
PRLIST(,TAPE20,)
CATALOG(TAPE20,$PRLIST JOB 1.023$,SN=DFC4405,ID=DFCDLS,RP=998)
REWIND(TAPE20)
COPY(TAPE20,OUTPUT)
EXIT(U)
REWIND(TAPE7)
ATTACH(LGO2,$LGO FOR FICHE PLOTS$,SN=DFC4405,ID=DFCDLS)
MAP(OFF)
LGO2.
EXIT(U)
REWIND(TAPE7)
CATALOG(TAPE7,$TAPE7 JOB 1.023$,SN=DFC4405,ID=DFCDLS,RP=998)
EXIT(U)
DISPOSE(FICHE,*PR=CFC,ST=COMNM)
DISPOSE(FICHE2,*FL=CFC,ST=COMNM)
REQUEST(FRED,*PF,SN=DFC4405)
FUSE.
TITLE(FICHE)
TITLE(FICHE2)
TRANZP(TAPE1,FL,FID=FICHE2)
CATALOG(TAPE1,$ZP FILE JOB 1.023$,SN=DFC4405,ID=DFCDLS,RP=999)
EXIT(U)
REWIND(OUTPUT)
COPY(OUTPUT,FICHE)
EXIT(U)
REWIND(OUTPUT)
COPY(OUTPUT,FRED)
CATALOG(FRED,$OUTPUT JOB 1.023$,SN=DFC4405,ID=DFCDLS,RP=20)
EXIT(U)
DISPOSE(OUTPUT,SC)
*EOS
 SAMPLE PROBLEM 2 - COPPER HEMISPHERE LOADED WITH COMP B HE UNCONFINED
 $OPTNS NPRTOP=2, TIMMAX=8000, IFLGST=1, IPMADJ=1, ITPHSE=1$
 $START PK(1)=1.02, PK(2)=0, PK(3)=-0$
 $RUN TSTOP=1.5E-04, PRDELT=2.0E-06, KUNITW=7, KUNITR=7, NOSLIP=0,
      LVISC=1, NMAT=2, NMXCLS=600, NTRACR=5, NTPMX=900, REZ=0.,
      CYCPH3=1, NLINER=1, NSLD=300, MAPS=1, IMAX=60, JMAX=132,
      DMIN=100, IPR=100, NFRELP=100, NDUMP7=1, IPCYCL=0, I1=3,
      I2=53, CVIS=-1, IGM=0$
  60                 .05
 999
 132                 .06666667
 999
```

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  2       8.90      0.0       0.0       0.0
 21       1.717     0.0       0.0       0.0
 2.35E+09  6.95E+10  5.50E+10  5.30E+09  4.55E+11    .9785
 0.0       0.0       0.0       0.0       0.0         1.0
  4    1   300
  3.14159  1.57080
 0.0       6.35      1.905
  1    1   50
 1.905     6.35      1.7907    6.35
 -4    1   300
  1.57080  3.14159
 0.0       6.35      1.7907
  1    2   100
 0.0       2.54      2.159     2.54
  2    2   200
  2.159    2.54      2.159     6.35
  1    2   50
  2.159    6.35      1.905     6.35
 -4    2   300
  1.57080  3.14159
 0.0       6.35      1.905
  4    3   300
  3.14159  1.57080
 0.0       6.35      1.7907
  1    3   50
  1.7907   6.35      1.905     6.35
  1    3   50
  1.905    6.35      2.159     6.35
  2    3   200
  2.159    6.35      2.159     2.54
 -1    3   100
  2.159    2.54      0.0       2.54
 100
  1    0    1    0   300       0
  0    2    0  351     0  650
       1         2       0.0       2.54      0.0
       2         2       1.82      5.62
       0
 0.0          2.54     2.159      6.35
 0.0          5.59     2.159      6.35
*EOS
LIST.
TOTAL(0,140000)
*EOS
TITLE1=$OUTPUT JOB 1.023$
TITLE2=$DAVID L. SMITH$
TITLE3=$WRITTEN "DATE"$
INDEX=1/1/25
*EOS
TITLE1=$PLOTS FOR JOB 1.023$
TITLE2=$DAVID L. SMITH$
TITLE3=$WRITTEN "DATE"$
PLOT
*EOP
```

APPENDIX 2

JOB TO RUN SHAPED CHARGE PROBLEM

```
SCRUN(P10,T20000,MS140000,ML600)
COMMENT. JOB TO RUN PROBLEM 50.0009
COMMENT.  PLANE WAVE DETONATION, MRL 38 MM CHARGE
LIMIT(0)
GETSET(DFC4405)
REQUEST(TAPE1,*PF,SN=DFC4405)
REQUEST(TAPE7,*PF,SN=DFC4405)
REQUEST(TAPE20,*PF,SN=DFC4405)
ATTACH,LGO,$LGO FOR MRLHLP20$,SN=DFC4405,ID=DFCDLS.
MAP(PART)
PRECON(FWA=0,LWA=140000)
LGO(PL=200000)
EXIT(U)
PRLIST(,TAPE20,)
CATALOG(TAPE20,$PRLIST JOB 50.0009$,SN=DFC4405,ID=DFCDLS,RP=998)
REWIND(TAPE20)
COPY(TAPE20,OUTPUT)
EXIT(U)
REWIND(TAPE7)
ATTACH(LGO2,$LGO FOR FICHE PLOTS$,SN=DFC4405,ID=DFCDLS)
MAP(OFF)
LGO2.
EXIT(U)
REWIND(TAPE7)
CATALOG(TAPE7,$TAPE7 JOB 50.0009$,SN=DFC4405,ID=DFCDLS,RP=998)
EXIT(U)
DISPOSE(FICHE,*PR=CFC,ST=COMNM)
DISPOSE(FICHE2,*FL=CFC,ST=COMNM)
REQUEST(FRED,*PF,SN=DFC4405)
FUSE.
TITLE(FICHE)
TITLE(FICHE2)
TRANZP(TAPE1,FL,FID=FICHE2)
CATALOG(TAPE1,$ZP FILE JOB 50.0009$,SN=DFC4405,ID=DFCDLS,RP=999)
EXIT(U)
REWIND(OUTPUT)
COPY(OUTPUT,FICHE)
EXIT(U)
REWIND(OUTPUT)
COPY(OUTPUT,FRED)
CATALOG(FRED,$OUTPUT JOB 50.0009$,SN=DFC4405,ID=DFCDLS,RP=20)
EXIT(U)
DISPOSE(OUTPUT,SC)
*EOS
 SHAPED CHARGE RUN ... MRL STANDARD 38 MM CHARGE
 $OPTNS IFLGST=1, IPMADJ=1, ITPHSE=1, NPRTOP=2, TIMMAX=7200$
 $START PK(1)=50.0009, PK(2)=0, PK(3)=0$
 $RUN BBAR=.5, CRATIO=1.0E04, CVIS=-1, CYCMX=2, CYCPH3=-1,
  DMIN=1.0E-03, DTMIN=1.0E-11, EMIN=1.0E07, FINAL=0.4,
  IEXTX=0, IGM=0, IMAX=60, IPR=35, I1=3, I2=13, JMAX=132,
  KUNITR=7, KUNITW=7, LVISC=1, MAPS=2, MINX=0, MAXX=40,
  MINY=27, MAXY=106, NADD=10, NDUMP7=1, NFRELP=20,
  NMXCLS=600, NLINER=1, NMAT=3, NSLD=300, NTCC=0,
  NTPMX=1800, NTRACR=3, PMIN=5.0E06, PRCNT=1.0E-03,
  PRDELT=1.0E-06, ROEPS=1.0E-05, SIEMIN=1.0E05, STAB=1.0E-03,
  ICSTOP=500$
```

```
  40    1    1    1    0.05        .0550       .0605       .0666
   1    1    1    1    .0732       .0805       .0886       .0974
   1    1    1    1    .1072       .1179       .1297       .1427
   1    1    1    6    .1569       .1726       .1899       .2000
 999
  12    1    1    1    .2000       .1899       .1726       .1569
   1    1    1    1    .1427       .1297       .1179       .1072
   1    1    1    1    .0974       .0886       .0805       .0732
   1    1    1   80    .0666       .0605       .0550       .0500
   1    1    1    1    .0550       .0605       .0666       .0732
   1    1    1    1    .0805       .0886       .0974       .1072
   1    1    1    1    .1179       .1297       .1427       .1569
   1    1   12         .1726       .1899       .2000
 999
     0
     2       8.9        0.0        0.0        0.0
    21       1.717      0.0        0.0        0.0
     4       2.79       0.0        0.0        0.0
   2.35E+09  6.95E+10  5.50E+10  5.30E+09  4.55E+11     0.9875
0.0        0.0        0.0        0.0        0.0        1.0
   3.00E+09  0.0        0.0       7.00E+09  2.74E+11     0.9850
     4     1   50
3.1416     2.1864
0.0        4.9972     0.4826
     3     1  300
0.3940     4.7185     1.905      8.6548
     2     1   30
1.905      8.6548     1.905      9.2898
     1     1   10
1.905      9.2898     1.8034     9.2898
     2     1   30
1.8034     9.2898     1.8034     8.6736
     3     1  300
1.8034     8.6736     0.3040     4.7675
    -4     1   50
2.2179     3,1416
0.0        4.9972     0.3810
     1     2  150
0.0        2.0        1.905      2.0
     2     2  150
1.905      2.0        1.905      8.6548
     3     2  300
1.905      8.6548     0.3940     4.7185
    -4     2   50
2.1864     3.1416
0.0        4.9972     0.4826
     1     3   10
1.905      2.0        2.2225     2.0
     2     3  180
2.2225     2.0        2.2225     9.2898
     1     3   10
2.2225     9.2898     1.905      9.2898
     2     3   30
1.905      9.2898     1.905      8.6548
    -2     3  150
1.905      8.6548     1.905      2.0
```

```
      4     4   50
 3.1416     2.2179
 0.0        4.9972     0.3810
      3     4  300
 0.3040     4.7675     1.8034      8.6736
      2     4   30
 1.8034     8.6736     1.8034      9.2898
      1     4   10
 1.8034     9.2898     1.905       9.2898
      1     4   10
 1.905      9.2898     2.2225      9.2898
      2     4  180
 2.2225     9.2898     2.2225      2.0
      1     4   10
 2.2225     2.0        1.905       2.0
     -1     4  150
 1.905      2.0        0.0         2.0
    100
      1     0     1    0   350     0
      0     2     0  151     0   650
      3     0   231    0   380     0
           99          2 0.0       2.0         0.0
0.0        2.0        1.91        8.66
*EOS
LIST.
TOTAL(0,140000)
*EOS
TITLE1=$OUTPUT JOB 50.0009$
TITLE2=$DAVID L. SMITH$
TITLE3=$WRITTEN "DATE"$
INDEX=1/1/25
*EOS
TITLE1=$PLOTS FOR JOB 50.0009$
TITLE2=$DAVID L. SMITH$
TITLE3=$WRITTEN "DATE"$
PLOT
*EOP
```

APPENDIX 3

LISTING OF SUBROUTINE MOVTCR

```
      SUBROUTINE MOVTCR                                                    MOVTCR
      COMMON/INF/ LJ,ICY                                                   MOVTCR
      COMMON/MOV/LS,UEFF,VEFF,KI(4),UTK(4),VTK(4),WF(4),MTK(4)             MOVTCR
C                                                                          MOVTCR
C*****************  FIT2  COMMON BLOCK   FOR MRLHELP...  ************      FIT2
      COMMON   Z(1)     ,CYCLE    ,DT       ,NUMSP    ,NFRELP   ,NDUMP7,   FIT2
     1 ICSTOP ,PIDY     ,TOPMU    ,RTMU     ,NOGAS    ,NUMREZ   ,ETH   ,   FIT2
     2 KUNITR ,IPR      ,PRCNT    ,KUNITW   ,IGROW    ,IDLT     ,NUN20 ,   FIT2
     3 IGM    ,SLPNDX   ,SLPNDY   ,DMIN     ,NIMAX    ,DTNA     ,CVIS  ,   FIT2
     4 JDBT   ,JDTP     ,NC       ,IDRT     ,NUN32    ,IMAX     ,NUN34 ,   FIT2
     5 JMAX   ,NUN36    ,KMAX     ,ICLADD   ,BOTM     ,BOTMV    ,NUMSPT,   FIT2
     6 MAPS   ,NUMSCA   ,PRLIM    ,PRDELT   ,PRFACT   ,I1       ,I2    ,   FIT2
     7 IPCYCL ,TSTOP    ,WFLAGF   ,WFLAGL   ,UN53     ,IVARDY   ,UN55  ,   FIT2
     8 IPLGRT ,RTM      ,RTMV     ,PLWMIN   ,IPLGBT   ,IPLGTP   ,GAMMA ,   FIT2
     9 TOPM   ,BOTMU    ,UN65     ,TOPMV    ,NUN67    ,NMAT     ,CYCMX ,   FIT2
      COMMON   CYCPH3   ,UN71     ,NTRACR   ,NMXCLS   ,BBOUND   ,ALPHA ,   FIT2
     1 ECK    ,NECYCL   ,NTPMX    ,UN79     ,UN80     ,NTCC     ,SIEMIN,   FIT2
     2 IVARDX ,T        ,EMIN     ,PMIN     ,INTER    ,I        ,J     ,   FIT2
     3 K      ,M        ,N        ,UN93     ,UN94     ,REZ      ,NODUMP,   FIT2
     4 UN97   ,UN98   ,MOVIE   ,EVAPM   ,EVAPEN   ,EVAPMU   ,EVAPMV,       FIT2
     5 EZPH2  ,NLINER   ,NSLPMX   ,NSLPMN   ,NENDMI   ,NVRTEX   ,ROEPS ,   FIT2
     6 PLGOPT ,NSLD     ,FINAL    ,UN114    ,NOSLIP   ,LVISC    ,NUN117,   FIT2
     7 NADD   ,MINX     ,MAXX     ,MINY     ,MAXY     ,IEXTX    ,JEXTY ,   FIT2
     8 PLUGON ,UN126    ,UN127    ,UN128    ,UMIN     ,UN130    ,PRTIME,   FIT2
     9 EOR    ,EOT      ,EOB      ,EMOR     ,DXF      ,DYF      ,SALPHA    FIT2
      COMMON   STAB     ,XIENRG   ,XKENRG   ,XTENRG   ,UN143    ,DTMIN ,   FIT2
     1 NUN145 ,EMOT     ,NUN147   ,CRATIO   ,BBAR     ,EMOB     ,          FIT2
     2          PK(5)                                                      FIT2
C                                                                          FIT2
C             NON-DIMENSIONED VARIABLES                                    FIT2
C                                                                          FIT2
                                                                           FIT2
      COMMON        CYC     ,ENERGY  ,ERDUMP  ,I3      ,KA      ,KR      , FIT2
     1              MA      ,MFK     ,MO      ,MOS     ,MR      ,NERR    , FIT2
     2              NK      ,NPRINT  ,NR      ,NVOID   ,PRESUR  ,PVRTEX  , FIT2
     3              RHOW    ,RMOM    ,SDT     ,TWOPI   ,TXCL    ,TYCL    , FIT2
     4              WS      ,WSA     ,WSB     ,WSC     ,WSX     ,WSY     , FIT2
     5              ZMOM    ,LAST                                          FIT2
      COMMON/TRACRS/ XP(1800),YP(1800)                                     FIT2
C                                                                          FIT2
      COMMON/MXCELL/ RHOZ(30),CNAUT(30),MAT(30)                            FIT2
      COMMON/MXCELL2/SAMMY(4,600),SGAMC(4,600),SAMPY(4,600),               FIT2
     2       SAMMP(4,600)                                                  FIT2
      LEVEL 2,SAMMY,SGAMC,SAMPY,SAMMP                                      FIT2
C                                                                          FIT2
      COMMON/SL/ SAMUT(4),SAMVT(4),SAMUR(4),SAMVR(4),SAMMU(4),SAMMV(4),    FIT2
     2           SSIGMU(4),SSIGMV(4)                                       FIT2
C                                                                          FIT2
      COMMON/SLIDE/ MSLD(300),XINT(2,300),YINT(2,300)                      FIT2
C                                                                          FIT2
      COMMON/SLIDPK/ NSLAVD(4),MASTRD(4),NENDMD(4),NBGMD(4),NENDSD(4),     FIT2
     2         NBGSD(4)                                                    FIT2
C                                                                          FIT2
      COMMON/MISC/ PQ(5,8),XAXIS(5,75),YAXIS(5,150),VL(4)                  FIT2
C                                                                          FIT2
```

```
      COMMON/PLSTC/ PLWP(352),PLWC(50,50),PVOL(50),ALPSV(50,50)
C
C
      COMMON/XDXYDY/ X00,X(75),Y00,Y(150),DX00,DX(75),DY00,DY(150)
C
C
C             THE SCALAR VARIABLES X00,Y00,DX00,DY00 MAKE AVAILABLE
C             X(0), Y(0), DX(0), DY(0)
C
      LEVEL 2, STRSRR,STRSRZ,STRSZZ,
     1                XMASS,SIE,US,VS,RHO,PLW,THETA,
     5             AMX,                AIX,                U,
     6             V,                  P,                  MFLAG,
     7             TAU,                UL,                 PL,
     8             TX,                 TY,                 NMP,
     9             RHOIN,              CZERO,              STK1,
     *             STK2,               STEZ,               RMU,
     1             AMDM,               SSIEN,              UUR,
     2             VVA,                OUTIE,              OUTKE,
     3             DETIM

      COMMON/OPTNS/IFLGST,IPMADJ,ITPHSE,NPRTOP,
     *TIMMAX

      COMMON/ELPL/ STRSRR(8001),STRSRZ(8001),STRSZZ(8001)
C
      COMMON/MXCEL1/                           XMASS(4,600),SIE(4,600),
     1  US(4,600),VS(4,600),RHO(5,600),PLW(4),THETA(600)
C
      COMMON/GRID/ AMX(8001),AIX(8001),U(8001),V(8001),P(8001),
     1   MFLAG(8001),TAU(75),UL(300),PL(300),TX(4,1800),
     2   TY(4,1800),NMP(5),RHOIN(4),CZERO(4),STK1(4),STK2(4),
     3              STEZ(4),RMU(4),AMDM(4),SSIEN(4),UUR(4),VVA(4),
     4              OUTIE(4),OUTKE(4),DETIM(8001)
C
C
C
C        ***SDLKEL,SDLKER,SDLKEB,SDLKET ARE KINETIC ENERGIES OF A GIVEN
C           MATERIAL TRANSPORTED ACROSS LEFT,RIGHT,BOTTOM AND TOP
C           BOUNDARIES OFAN INTERFACE CELL
C        ***DLKEL IS KINETIC ENERGY OF MASS TRANSPORTED ACROSS LEFT
C           SIDE OF CELL
      LEVEL 2, IDT,JDT,FRACRT,DELP,DNS,PRS,CSQR,VOL,WSQR,PROP,PR,
     2 FRACTP,FLEFT,YAMC,GAMC,SIGC,SDELET,SDELER,SDELEB,SDELM,SSIGC,UTL,
     3 VTL,UTRANS,VTRANS,SYAMC,SFLEFT,XMAS,SSIE,XRH,USSAVE,VSSAVE,THET,
     4 MFGREZ,REZAMX,REZAIX,REZXMS,REZSIE,REZRHO,SDLKEL,SDLKER,SDLKEB,
     5 SDLKET,DLKEL
C
      COMMON/ADDENG/ IDT(8001),JDT(3200),FRACRT(5,600)
C
C
      COMMON/CDT/ DELP(4),DNS(3,4),PRS(3,4),CSQR(4),VOL(4),WSQR(4)
C
C
      COMMON/MAP/    PROP(60), PR(60)
```

```
C                                                                         FIT2       107
      COMMON/INFACE/ FRACTP(5,600)                                        FIT2       108
C                                                                         FIT2       109
      COMMON/PH2/ FLEFT(150),YAMC(150),GAMC(150),SIGC(150),SDELET(4),     FIT2       110
     1            SDELER(4),SDELEB(4),SDELM(4),SSIGC(4,150),UTL(4,150),   FIT2       111
     2            VTL(4,150),UTRANS(4,4),VTRANS(4,4),SYAMC(4,150),        FIT2       112
     3            SFLEFT(4,150),SDLKEL(4,150),SDLKER(4),SDLKEB(4),        FIT2       113
     4            SDLKET(4),DLKEL(150)                                    FIT2       114
C                                                                         FIT2       115
C                                                                         FIT2       116
      COMMON/REZONE/ XMAS(2,4),SSIE(2,4),XRH(2,4),USSAVE(2,4),            FIT2       117
     1               VSSAVE(2,4),THET(2),MFGREZ(150),REZAMX(150),         FIT2       118
     2               REZAIX(150),REZXMS(4,150),REZSIE(4,150),             FIT2       119
     3               REZRHO(4,150),STKEGM(2,4)                            FIT2       120
C                                                                         FIT2       121
C        ***TKEG IS SPECIFIC KINETIC ENERGY IN A CELL                     FIT2       122
C        ***TKEGM IS SPECIFIC KINETIC ENERGY OF MATERIALS IN INTERFACE    FIT2       123
C           CELLS                                                         FIT2       124
      LEVEL 2,TKEG,TKEGM                                                  FIT2       125
      COMMON/KEGCHK/TKEG(8001),TKEGM(4,600)                               FIT2       126
      COMMON/ERRDEC/ IRAY(6)                                              FIT2       127
      DIMENSION VOLM(5,600)                                               FIT2       128
      DIMENSION XO(2),YO(2),DXO(2),DYO(2)                                 FIT2       129
      DIMENSION CYCLE1(40)                                                FIT2       130
C                                                                         FIT2       131
      LEVEL 2, XP,YP,MSLD,XINT,YINT,PQ,XAXIS,YAXIS,VL,                    LCMFIX       1
     1  PLWP,PLWC,PVOL,ALPSV,X00,X,Y00,Y,DX00,DX,DY00,DY                  LCMFIX       2
C                                                                         FIT2       132
      EQUIVALENCE (Z(1),PROB),      (PIDY,PI)                             FIT2       133
C                                                                         FIT2       134
C             SPECIAL EQUIVALENCE FOR SETUP                               FIT2       135
C                                                                         FIT2       136
      EQUIVALENCE (SAMMY,VOLM)                                            FIT2       137
C                                                                         FIT2       138
C                                                                         FIT2       139
      EQUIVALENCE (XO(2),X(1)),(YO(2),Y(1)),(DXO(2),DX(1)),(DYO(2),DY(1)  FIT2       140
     1)                                                                   FIT2       141
      EQUIVALENCE(CYCLE1(1),CYCLE)                                        FIT2       142
C                                                                         FIT2       143
C                                                                         FIT2       144
C             DATA STATEMENTS FOR MATERIALS DEFINED IN EQST.              FIT2       145
C             NOTE - IDEAL GAS REFERENCE DENSITY RHOZ(20) IS DEFINED TO   FIT2       146
C                    BE THE NORMAL DENSITY OF AIR. THE USER SHOULD        FIT2       147
C                    CHANGE THIS VALUE IF USING ANOTHER MATERIAL.         FIT2       148
      DATA (RHOZ(K),K=1,19)  /19.17  ,8.9    ,7.8    ,2.79   ,1.8      ,  FIT2       149
     1                        4.5    ,8.9    ,10.2   ,11.7   ,11.3     ,  FIT2       150
     2                        .9     ,2.7    ,2.7    ,1.97   ,1.7      ,  FIT2       151
     3                        2.3    ,2.8    ,2.7    ,2.2    /            FIT2       152
                                                                          FIT2       153
      DATA RHOZ(20)   /.001293/                                           FIT2       154
C                                                                         FIT2       155
      DATA(RHOZ(K),K=21,25)/1.717,1.63,1.821,1.84,1.608/                  FIT2       156
C                                                                         FIT2       157
      DATA (CNAUT(K),K=1,19) /4.01E5 ,3.95E5 ,4.03E5 ,5.27E5 ,8.06E5   ,  FIT2       158
     1                        4.78E5 ,4.63E5 ,5.15E5 ,2.13E5 ,2.03E5   ,  FIT2       159
```

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     2                         2.89E5 ,2.58E5 ,2.58E5 ,2.24E5 ,1.63E5   , FIT2       160
     3                         3.49E5 ,5.51E5 ,3.85E5 ,3.37E5 /           FIT2       161
C                                                                         FIT2       162
C*****CALL SYSTEMC TO INHIBIT PRINTING OF ERROR 115 AND                   FIT2       163
C     START ERROR SUMMARY ACCUMULATION.                                   FIT2       164
      DATA IRAY/6*( 0)/                                                   FIT2       165
      CALL SYSTEMC (115,IRAY)                                             FIT2       166
C*****************   END  COMMON BLOCK   FOR MRLHELP... ************      FIT2       167
C                                                                         MOVTCR       7
C                                                                         MOVTCR       8
C                                                                         MOVTCR       9
C                                                                         MOVTCR      10
C*********************************************************************** MOVTCR      11
C                                                                         MOVTCR      12
C             *** MOVE TRACERS.                                           MOVTCR      13
C                                                                         MOVTCR      14
      NVP=NVOID                                                           MOVTCR      15
      NV=NMP(NVOID)-1                                                     MOVTCR      16
C             *** WHEN NTCC.GT.1, PASSIVE CELL CENTERED TRACERS (XP,YP)   MOVTCR      17
C                           ARE BEING PROCESSED.                          MOVTCR      18
C                 WHEN NTCC=0, THESE TRACERS HAVE NOT BEEN GENERATED.     MOVTCR      19
      DO 1530 N=1,NVP                                                     MOVTCR      20
      NN=NMP(N)-1                                                         MOVTCR      21
      IF (N.EQ.NVOID) NN=NTCC                                             MOVTCR      22
                                                                          MOVTCR      23
      IF (NN.EQ.0) GO TO 1530                                             MOVTCR      24
C             *** CELL-CENTERED TRACERS MOVED ONLY ONCE PER CYCLE         MOVTCR      25
      IF (N.GT.NMAT.AND.LJ.LT.ICY) GO TO 1530                             MOVTCR      26
      DO 1520 LL=1,NN                                                     MOVTCR      27
      L=NN-LL+1                                                           MOVTCR      28
C             *** FIND I AND J OF CELL TRACER IS IN BEFORE IT IS MOVED.   MOVTCR      29
      IF (N.LT.NVP) GO TO 1180                                            MOVTCR      30
      I=INT(XP(L))+1                                                      MOVTCR      31
      IF(XP(L).GE.FLOAT(IMAX))I=I-1                                       TRLOGIC      1
      J=INT(YP(L))+1                                                      MOVTCR      32
      IF(YP(L).GE.FLOAT(JMAX))J=J-1                                       TRLOGIC      2
      GO TO 1230                                                          MOVTCR      33
 1180 CONTINUE                                                            MOVTCR      34
      IF (TX(N,L).LE.-1000.) GO TO 1520                                   MOVTCR      35
      I=INT(TX(N,L))+1                                                    MOVTCR      36
      IF (TX(N,L).GE.FLOAT(IMAX)) I=I-1                                   MOVTCR      37
      J=INT(TY(N,L))+1                                                    MOVTCR      38
      IF (TY(N,L).GE.FLOAT(JMAX)) J=J-1                                   MOVTCR      39
C                                                                         MOVTCR      40
C             *** FIND INDEX OF CORRESPONDING FREE SURFACE TRACER         MOVTCR      41
C                 IF THERE IS ONE.                                        MOVTCR      42
C                                                                         MOVTCR      43
                                                                          MOVTCR      44
      LVF=0                                                               MOVTCR      45
      IF (NV.LE.0) GO TO 1220                                             MOVTCR      46
C                                                                         MOVTCR      47
      DO 1200 LLV=1,NV                                                    MOVTCR      48
      LV=NV-LLV+1                                                         MOVTCR      49
      IF (TX(N,L)-TX(NVOID,LV)) 1200,1190,1200                            MOVTCR      50
 1190 IF (TY(N,L)-TY(NVOID,LV)) 1200,1210,1200                            MOVTCR      51
```

```
 1200 CONTINUE                                                          MOVTCR    52
      GO TO 1220                                                        MOVTCR    53
 1210 LVF=LV                                                            MOVTCR    54
C                                                                       MOVTCR    55
 1220 CONTINUE                                                          MOVTCR    56
C            *** IF TRACER IS OUTSIDE GRID, SKIP OUT.                   MOVTCR    57
 1230 CONTINUE                                                          MOVTCR    58
      IF (I.GT.I1.OR.J.GT.I2.OR.J.LT.0) GO TO 1520                      MOVTCR    59
C                                                                       MOVTCR    60
      K=(J-1)*IMAX+I+1                                                  MOVTCR    61
      M=IABS(MFLAG(K))-100                                              MOVTCR    62
C                                                                       MOVTCR    63
C            *** STORE FRACTIONAL PARTS OF THE COORDINATES IN FRX,FRY.  MOVTCR    64
                                                                        MOVTCR    65
C                                                                       MOVTCR    66
      IF (N.LT.NVP) GO TO 1240                                          MOVTCR    67
      FRX=XP(L)-AINT(XP(L))                                             MOVTCR    68
      FRY=YP(L)-AINT(YP(L))                                             MOVTCR    69
C     THIS LOGIC CHANGED BY DLS 30.8.83 TO ACCOUNT FOR TRACERS          TRLOGIC    3
C     ON FAR EDGE OF LAST ROW OR COLUMN, WHICH WERE PREVIOUSLY          TRLOGIC    4
C     TREATED AS BEING ON NEAR EDGE, AS FRX WAS 0.0                     TRLOGIC    5
      IF(XP(L).GE.FLOAT(IMAX))FRX=1.0                                   TRLOGIC    6
      IF(YP(L).GE.FLOAT(JMAX))FRY=1.0                                   TRLOGIC    7
      GO TO 1250                                                        MOVTCR    70
 1240 CONTINUE                                                          MOVTCR    71
      FRX=TX(N,L)-AINT(TX(N,L))                                         MOVTCR    72
      FRY=TY(N,L)-AINT(TY(N,L))                                         MOVTCR    73
      IF(TX(N,L).GE.FLOAT(IMAX))FRX=1.0                                 TRLOGIC    8
      IF(TY(N,L).GE.FLOAT(JMAX))FRY=1.0                                 TRLOGIC    9
 1250 CONTINUE                                                          MOVTCR    74
      WSX=ABS(FRX-.5)                                                   MOVTCR    75
      WSY=ABS(FRY-.5)                                                   MOVTCR    76
C                                                                       MOVTCR    77
C            *** DEFINE INDICES OF NEIGHBOR CELLS.                      MOVTCR    78
      KV=K+IMAX                                                         MOVTCR    79
      IF (FRY.GE..5.AND.J.EQ.JMAX) GO TO 1260                           MOVTCR    80
      IF (FRY.GE..5) GO TO 1280                                         MOVTCR    81
      IF(J.GT.1)GOTO 1270                                               TRLOGIC2   1
C     NOTE NEXT COMMENT NOT TRUE (AND NEVER WAS!) HENCE THIS FIX        TRLOGIC   11
C            *** FRY=0. MEANS POINT IS ON TOP OR BOTTOM GRID BOUNDARY   MOVTCR    83
 1260 KV=K                                                              MOVTCR    84
      GO TO 1280                                                        MOVTCR    85
                                                                        MOVTCR    86
 1270 KV=K-IMAX                                                         MOVTCR    87
C                                                                       MOVTCR    88
 1280 KH=K+1                                                            MOVTCR    89
      KD=KV+1                                                           MOVTCR    90
      IF (FRX.GE..5.AND.I.EQ.IMAX) GO TO 1290                           MOVTCR    91
      IF (FRX.GE..5) GO TO 1310                                         MOVTCR    92
      IF(I.GT.1)GOTO 1300                                               TRLOGIC2   2
C     NOTE NEXT COMMENT NOT TRUE (AND NEVER WAS!) HENCE THIS FIX        TRLOGIC   13
C            *** FRX=0. MEANS POINT IS ON LEFT OR RIGHT GRID BOUNDARY   MOVTCR    94
 1290 KH=K                                                              MOVTCR    95
C     BRL VERSION HAD ERROR HERE OF KD=K                                TRLOGIC   14
      KD=KV                                                             TRLOGIC   15
```

```
      GO TO 1310
 1300 KH=K-1
      KD=KV-1
C
 1310 CONTINUE
C
      JV=(KV-2)/IMAX+1
      JH=(KH-2)/IMAX+1
      IH=KH-(JH-1)*IMAX-1
C

C             *** DEFINE WEIGHTING FACTORS
      WH=0.
      WV=0.
      WD=0.
      WK=0.
      WFS=0.
      WH=WSX*(1.0-WSY)*AMX(KH)/(TAU(IH)*DY(J))
      WV=WSY*(1.0-WSX)*AMX(KV)/(TAU(I)*DY(JV))
      WD=WSX*WSY*AMX(KD)/(TAU(IH)*DY(JV))
      WK=(1.0-WSY)*(1.0-WSX)*AMX(K)/(TAU(I)*DY(J))
C
      WF(1)=WK
      WF(2)=WV
      WF(3)=WD
      WF(4)=WH
      KI(1)=K
      KI(2)=KV
      KI(3)=KD
      KI(4)=KH
      MTK(1)=M

      MTK(2)=IABS(MFLAG(KV))-100
      MTK(3)=IABS(MFLAG(KD))-100
      MTK(4)=IABS(MFLAG(KH))-100
C
C             *** IF THIS IS AN IMPACT CALCULATION WITH PLUGGING
C                 FAILURE, COMPUTE VELOCITY COMPONENTS OF PROJECTILE,
C                 PLUG AND TARGET TRACERS IN SUBROUTINE PLUGUV
C
      IF(PLUGON.LE.0. .OR. N.GT.3) GO TO 1305
      LS=L
      CALL PLUGUV
      GO TO 1360
 1305 CONTINUE
C
      DO 1330 IK=1,4
```

```
      WFS=WF(1)+WF(2)+WF(3)+WF(4)
C
C            *** IF WFS=0. THERE IS NO MASS IN THE OVERLAP CELLS. SO
C                THAT THIS PARTICLE WILL NOT BE LEFT BEHIND IT IS MOVED
C                TO THE POSITION OF THE L+1 PARTICLE UNLESS L=NN, IN
C                WHICH CASE IT IS MOVED TO THE POSITION OF THE L-1
C                PARTICLE.  IN ANY CASE, IF IT IS ON A GRID LINE IT IS
C                ONLY MOVED ALONG THAT GRIDLINE.
C
      IF(N.EQ.NVP .OR. WFS.GT.0.) GO TO 1335
      NT=1
C     THIS FIX BY DLS TO PREVENT TRACERS 1 AND NN GETTING STUCK.
C     IT APPEARS THIS WAS INTENDED ORIGINALLY, AT LEAST FOR THE
C     L=NN CASE.  THE PROBLEM BECAME MORE LIKELY TO ARISE WITH
C     THE USE OF THE DEGAS ROUTINE TO ISOLATE PACKAGE ONE.
C
      IF(L.EQ.NN)NT=-1
      IF(TX(N,L+NT).LE.-1000.)GO TO 1505
C     ***NOTE PREVIOUSLY THE PROG SKIPPED TO 1505 IF L WAS 1 OR NN.
C     ***ALSO TX FOR L+1 AND L-1 WERE TESTED, WITHOUT USING NT=-1.
C
      IF(TX(N,L).GT.0.  .AND.  TX(N,L).LT.FLOAT(IMAX)) TX(N,L)=TX(N,L+NT)
      IF(TY(N,L).GT.0.  .AND.  TY(N,L).LT.FLOAT(JMAX)) TY(N,L)=TY(N,L+NT)
      GO TO 1505
C
 1335 CONTINUE
C            *** CALCULATE RADIAL VELOCITY OF THE TRACER.

      IF (I.GT.1.OR.FRX.GE.(.5)) GO TO 1340
      WF(3)=-WF(3)
      WF(4)=-WF(4)
 1340 CONTINUE
      UEFF=(UTK(1)*WF(1)+UTK(2)*WF(2)+UTK(3)*WF(3)+UTK(4)*WF(4))/WFS
      WF(3)=ABS(WF(3))
      WF(4)=ABS(WF(4))
C            *** CALCULATE AXIAL VELOCITY OF THE TRACER.
      IF (J.GT.1.OR.CVIS.LT.0..OR.FRY.GE.(.5)) GO TO 1350
      WF(2)=-WF(2)
      WF(3)=-WF(3)
 1350 CONTINUE
      VEFF=(VTK(1)*WF(1)+VTK(2)*WF(2)+VTK(3)*WF(3)+VTK(4)*WF(4))/WFS
 1360 CONTINUE
      IF (ABS(UEFF).LT.UMIN) UEFF=0.
      IF (ABS(VEFF).LT.UMIN) VEFF=0.
C            *** CELL-CENTERED TRACERS MOVED ONLY ONCE PER CYCLE
      IF (N.GT.NMAT.AND.LJ.EQ.ICY) SDT=DT
      DISTX=UEFF*SDT
      DISTY=VEFF*SDT
      POSX=X(I-1)+DX(I)*FRX+DISTX
      POSY=Y(J-1)+DY(J)*FRY+DISTY
C
      IF (N.LT.NVP) GO TO 1500
C      *** DO NOT MOVE TRACERS OFF OF GRID BOUNDARIES
      IF(XP(L) .GT. 0. .AND. XP(L) .LT. FLOAT(IMAX)) XP(L)=XPTOC(POSX)
      IF(YP(L).GT.0. .AND. YP(L).LT. FLOAT(JMAX)) YP(L)=YPTOC(POSY)
```

```
      IF (XP(L).LT.0.) XP(L)=0.
      IF (YP(L).LT.0.) YP(L)=0.

      GO TO 1510
C     *** DO NOT MOVE TRACERS OFF OF GRID BOUNDARIES ***
 1500 IF(TX(N,L).GT. 0. .AND. TX(N,L).LT.FLOAT(IMAX))TX(N,L)=XPTOC(POSX)
      IF(TY(N,L).GT. 0. .AND. TY(N,L).LT.FLOAT(JMAX))TY(N,L)=YPTOC(POSY)
C             *** IF TRACER CROSSED AXIS, PUT IT BACK ON AXIS.
      IF (TX(N,L).LT.0.) TX(N,L)=0.
      IF (TY(N,L).LT.0.) TY(N,L)=0.
      IF (TX(N,L).GT.FLOAT(IMAX)) TX(N,L)=FLOAT(IMAX)
      IF (TY(N,L).GT.FLOAT(JMAX)) TY(N,L)=FLOAT(JMAX)
      IF (N.EQ.NLINER.AND.TX(N,L).LE.0..AND.L.GT.1.AND.L.LT.NN) TX(N,L)=
     1.0001
C             *** MOVE CORRESPONDING FREE SURFACE TRACER IF THERE IS ONE
 1505 IF(LVF.EQ.0) GO TO 1510
      TX(NVOID,LVF)=TX(N,L)
      TY(NVOID,LVF)=TY(N,L)
C
 1510 CONTINUE
C             *** END OF LOOP ON L
 1520 CONTINUE
C             *** END OF LOOP ON MATERIALS (MN)
 1530 CONTINUE

      IF (PLGOPT.LE.0.) GO TO 1535
C             *** BEFORE PLUG BEGINS TO FORM, SLPNDX AND SLPNDY
C                 ARE DEFINED TO BE EQUAL TO THE COORDINATES OF
C                 THE TRACER AT THE BEGINNING OF THE SLIPLINE.
      IF(PLUGON.GT.0.) GO TO 1535
      NB=NBGSD(2)
      SLPNDX = TX(2,NB)
      SLPNDY = TY(2,NB)
 1535 CONTINUE
C           *** CLOSE VOID IF NVRTEX.GT.0. NVRTEX IS THE NUMBER OF THE
C               VOID TRACER WHICH IS THE VERTEX OF THE REGION TO BE
C               CLOSED
C
      IF(NVRTEX.GT.0) CALL VDCLOS
C
C             *** AFTER THE PLUG IS COMPLETELY FORMED, ALL THE SLIDE
C                 TRACERS ARE MOVED WITH PLUG AND PROJECTILE VELOCITIES
C                 EXCEPT THE TOP TRACER. THE TRACERS BEHIND THE TOP
C                 POINT WILL USUALLY HAVE A LARGER AXIAL COMPONENT OF
C                 VELOCITY AND WILL EVENTUALLY TRY TO PASS THE TOP

C                 TRACER. SUBROUTINE ENDMV IS CALLED TO PREVENT THE
C                 TRACERS BEHIND FROM BYPASSING THE TOP TRACER.
C
      IF (PLGOPT.LE.0.) RETURN
      IF (TX(3,1).GT.0.) CALL ENDMV
      RETURN
C
      END
```

APPENDIX 4

AN UPDATE RUN TO ADD SUBROUTINE TCRCHK

TO THE HELP CODE

```
MAKE21,P1000,T100.
GETSET,DFC4405.
ATTACH,OLDPL,MRLHLP20,SN=DFC4405,ID=DFCDLS.
REQUEST,NEWPL,*PF,SN=DFC4405.
REQUEST,LGO,*PF,SN=DFC4405.
UPDATE,F,N,L=A1.
FTN,D=TAPE33,I=COMPILE,SL=0,LCM=I.
CATALOG,NEWPL,$MRLHLP21$,SN=DFC4405,ID=DFCDLS,RP=998.
CATALOG(LGO,$LGO FOR MRLHLP21$,SN=DFC4405,ID=DFCDLS,RP=998)
*EOS
*IDENT SPEEDUP
*DELETE FIT2.71
     3         DETIM,          COINC
*DELETE FIT2.85
     4  OUTIE(4),OUTKE(4),DETIM(8001),COINC(1800)
*INSERT ADDTCR.27
      NADDED=0
*INSERT ADDTCR.93
      NADDED=NADDED+NADD
*INSERT ADDTCR.179
      WRITE(6,301)NADDED
      IF(NADDED.LE.0)GOTO 300
      CALL TCRCHK
300   CONTINUE
301   FORMAT(//,1X,I5,2X,13HTRACERS ADDED)
*INSERT MAIN.17
C     FILL COINC ARRAY TO CHECK FOR COINCIDENT TRACERS ON SETUP
C     OR RESTART OF PROBLEM
      CALL TCRCHK
*DELETE MOVTCR.41,56
*DELETE MOVTCR.213,217
1505  CONTINUE
*INSERT MOVTCR.222
C     MOVE FREE SURFACE TRACERS
C     NOTE ALL VOID TRACERS ARE NOW FLAGGED TO A TRACER OF ANOTHER
C     MATERIAL.  ARRAY COINC HOLDS THIS INFO, PACKAGE NUMBER AND MATERIAL
C     NUMBER PACKED INTO ONE WORD.  SUBROUTINE TCRCHK UPDATES THIS ARRAY
C     AS REQUIRED.
      IF(NV.LE.0)GOTO 2001
      DO 2000 I=1,NV
      CC=COINC(I)
      IF(CC.LE.0.0)GOTO 2000
      NPACK= INT((CC-AINT(CC))*10.0)
      NTCR= INT(CC)
      TX(NVOID,I)=TX(NPACK,NTCR)
      TY(NVOID,I)=TY(NPACK,NTCR)
2000  CONTINUE
2001  CONTINUE
*INSERT VDCLOS.140
      CALL TCRCHK
*ADDFILE
*DECK TCRCHK
      SUBROUTINE TCRCHK
*CALL COMDK
C     THIS SUBROUTINE CHECKS FOR COINCIDENT TRACERS WITH THE VOID
C     PACKAGE.  THIS INFORMATION IS NEEDED BY SUBROUTINE MOVTCR,
```

```
C     WHICH PREVIOUSLY RE-CHECKED EVERY CYCLE, EVEN WHEN NO CHANGES
C     WERE POSSIBLE FROM THE PREVIOUS CHECKS.
C
C     TCRCHK IS CALLED BY MAIN AFTER SETUP IS CALLED, EITHER FOR A
C     NEW PROBLEM OR A RESTART.
C     TCRCHK IS ALSO CALLED BY ADDTCR WHEN NEW TRACERS ARE ADDED
C     AND BY VDCLOS WHEN A VOID IS CLOSED.
C
C            WRITTEN BY DAVID L. SMITH  APRIL 1984.
C
C
      NV=NMP(NVOID)-1
      IF(NV.LE.0)RETURN
      DO 100 NN=1,NV
      COINC(NN)=0.0
      TXV=TX(NVOID,NN)
      IF(TXV.LE.-1000.)GOTO 100
      TYV=TY(NVOID,NN)
      DO 110 NPACK=1,NMAT
      NT=NMP(NPACK)-1
      DO 120 NTCR=1,NT
      IF(TXV.EQ.TX(NPACK,NTCR).AND.TYV.EQ.TY(NPACK,NTCR))GOTO 130
120   CONTINUE
110   CONTINUE
      GOTO 100
130   COINC(NN)=FLOAT(NTCR)+(FLOAT(NPACK)  + .001)/10.0
100   CONTINUE
      WRITE(6,200)
      RETURN
200   FORMAT(//,34H SUBROUTINE TCRCHK HAS BEEN CALLED,//)
      END
*EOP
```

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