SCIENTIFIC NOTEBOOK

170-15E

SCIENTIFIC NOTEBOOK
No. 170-15e

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INITIAL ENTRIES

Scientific Notebook No.:	170-15e
Issued to:	Christopher J. Grossman
Issue Date:	March 26, 2002
Account Number:	20-10402-762
Title:	DSFAIL
Participants:	Osvaldo Pensado, Ronald Janetzke

PREFACE

This notebook contains a record of procedures for modification and testing of a proposed drip shield module (DSFAIL) for the Total-system Performance Assessment (TPA) Version 5.0 Code. TPA Version 5.0 Code is being prepared by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the U.S. Nuclear Regulatory Commission (NRC). DSFAIL was proposed by the CNWRA as modification DS1 to TPA for Version 5.0 in the "Software Requirements Description for the TPA Version 5.0 Code" submitted to NRC on December 7, 2001. The addition of DSFAIL to TPA is documented in Software Change Report (SCR) No. PA-SCR-348 (Software Version TPA 4.2), Project No. 20-1402-762.

SUMMARY OF
SOFTWARE CHANGE REPORT
PA-SCR-348

Affected Software Module(s), Description of Problem(s):

DS1 Drip Shield Failure Model

Currently, the drip shield model is limited to the specification of a single failure time. It is desired to have a parametric model that considers general corrosion rates and fluoride concentration and allows flexibility to consider mechanical failure modes (such as due to rockfall). The new parametric model will be coded in a new TPA module called DSFAIL. It will interface to the TPA executive in a manner similar to the other modules; that is, DSFAIL will receive near-field chemistry information in a manner similar to the EBSFAIL module and return drip shield failure times to the executive. The drip shield failure times will affect water contacting the waste package and the near-field chloride concentration. The module will be designed so that mechanical failures of the drip shield and waste package are treated consistently.

Change Requested by: R. Janetzke
Date: 01/14/02

Change Authorized by: R. Janetzke
Date: 01/14/02

Description of Change(s) or Problem Resolution (*If changes not implemented, please justify*)

DSFAIL

The DSFAIL module will call the stand-alone code, *DSfailt.e*, to compute the failure time of the drip shield by general corrosion, allowing for the enhancement of corrosion due to fluoride. For each realization, *DSfailt.e* will input data for the drip shield corrosion rate, thickness, minimum fluoride concentration affecting the corrosion rate, and maximum fluoride concentration affecting the corrosion rate from *DSfailt.inp*; realization time steps and fluoride concentrations from *fluoride.txt*. *DSfailt.e* will then compute the time dependency of penetration depth due to general corrosion, including any enhancement from fluoride, and the time of drip shield failure. *DSfailt.e* then outputs the drip shield thickness and failure time data to *DSThickness.txt*.

Implemented by: O. Pensado, C. Grossman
Date:

Description of Acceptance Tests:

See TPA Version 4.2 Test Plan: PA-SCR-348 for details.

Written by:
Tested by:
Date:

ENTRIES

MARCH 28, 2002

Back-up copies of O. Pensado's files.
Created subdirectory dsfail_rev0 and moved original DSFAIL files, received from O. Pensado, in dsfail_rev0..
Created subdirectory dsfail_rev1 and placed copies of the originals in dsfail_rev1.
All modifications will be performed on files in dsfail_rev1.

MARCH 29, 2002

Correct I/O error from *Dsfailt.e*.
Compile *DSfailt.e* in dsfail_rev1 directory:

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{20}>make
f77 DSfailt.o DSfailtime.o DSenhance.o library/int.o library/linearInterp.o library/searchPosition.o -o
DSfailt.e
```

Run *DSfailt.e*

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{23}>DSfailt.e
```

Receive following output:

```
list io: [1009] no * after repeat count
logical unit 7, named 'DSfailt.inp'
lately: reading sequential list external IO
part of last format: ext list io
part of last data: 1.|0e-08
Abort
```

Edit *DSfailt.inp*

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{31}>vi DSfailt.inp
"DSfailt.inp" 14 lines, 858 characters
Input file for module DSfailt
This file is rewritten for each realization
================================================
fluoride.txt     fileIn, Input data file, fluoride concentration versus time
DSPenDepth.txt   fileOut1, Output data file 1, tracking penetration depth vs time
DSFailTime.txt   fileOut2, Output data file 2, failure time of the drip shield
1.0e-08          cr, m/yr, drip shield corrosion rate : DSCorrRate[m/yr]
0.015            dsThick, m, drip shield thickness : DripShieldThickness[m]
1.8              slope, dimensionless, slope of drip shield enhancing factor : TiCorrRateVsFluorideSlope
1.0e-04          minF, M, minimum fluoride concentration affecting the DS corrosion rate :
MinimumFluoride[Molar]
2.0e-03          maxF, M, maximum fluoride concentration affecting the DS corrosion rate :
MaximumFluoride[Molar]
TPATime.txt      fileTPAtime, Input file containing the TPA time steps
[Esc]:wq
```

Edit *Dsfailt.f*

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{58}>vi DSfailt.f
"DSfailt.f" 244 lines, 8778 characters
c Program Name:        DSfailt
c File Name:           DSfailt.f
        :
        :
        parameter (fileID1=7, InputFile='DSfailt.inp')

9001      format(2(1pe12.4,2x))

        open (fileID1, file=InputFile, status='old')
        do i=1,3
                       read (fileID1, *) aline
        end do
        read (fileID1,␣*) fileIn
        read (fileID1,␣*) fileOut1
        read (fileID1,␣*) fileOut2
        read (fileID1,␣*) cr
```

```
        read (fileID1,␣*) dsThick
        read (fileID1,␣*) slope
        read (fileID1,␣*) minF
        read (fileID1,␣*) maxF
        read (fileID1,␣*) fileTPAtime
        close(fileID1)
:wq
"DSfailt.f" 244 lines, 8778 characters
/net/spock/home/cgrossman/dsfail/dsfail_rev1{59}>make
f77 -g -C  -c  DSfailt.f
DSfailt.f:
MAIN dsfail:
f77 DSfailt.o DSfailtime.o DSenhance.o library/int.o library/linearInterp.o library/searchPosition.o -o
DSfailt.e
/net/spock/home/cgrossman/dsfail/dsfail_rev1{60}>DSfailt.e

Error: minimum fluoride must be greater than maximum fluoride
Both fluoride concentrations must be strictly positive
minimum fluoride =     1.8000000000000 Molar
maximum fluoride =     1.0000000000000D-04 Molar
```

✓ I/O Error Corrected

April 2, 2002

Improve logic to ALWAYS create DS thickness vs time file.

Currently, the file tracking the DS thickness vs. time is only created if the DS fails for the particular realization. Need to adjust logic to always create this output file.

Edit *Dsfailt.f*. Removed the noted lines for comment.

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1>vi DSfailt.f
cccccccccccccccc
c THESE LINES REMOVED TO ALWAYS CREATE DS THICKNESS VS TIME FILE
c     if (flag.eq.1) then
c
c         print *, ' '
c         print *, 'DS failure time = ', nint(tf), ' years'
cccccccccccccccc
```

Edit Dsfailt.f. Added the noted lines.

```
cccccccccccccccc
c BEGIN OF LINES ADDED TO ALWAYS CREATE DS THICKNESS VS TIME FILE
cccccccccccccccc

cccccccccccccccc
c Interpolate penetration depths for TPA time steps
cccccccccccccccc
     do  i=1,TimeSteps
c  Recall that b contains time in 1st column and penetration depth in 2nd column.
        x(i,1) = b(i,1)
        y(i,1) = b(i,2)
      end do

      if (flag.eq.1) then

   print *, ' '
         print *, 'DS failure time = ', nint(tf), ' years'
   low = searchPosition(timeTPA,tf,TPATimeSteps)

      else
   print *, ' '
         print *, 'No failure of DS in ', nint(b(TimeSteps,1)), ' years'
   low = TPATimeSteps

      end if
      do  i=1,low
   penDepth(i,1) = linearInterp(x,y,TimeSteps,timeTPA(i,1))
      end do
cccccccccccccccc
c End of interpolated depths
cccccccccccccccc

      open (fileID1, file=fileOut1, status='unknown')
cccccccccccccccc
c Janetzke  --> introduce additional QA requirements (time file was created, etc)
cccccccccccccccc
      write (fileID1,*) 'GENERATING MODULE: DSfailt'
      write (fileID1,*) 'Uniform corrosion of drip shield'
      write (fileID1,*) 'Corrosion front penetration depth vs time'
      write (fileID1,*) low+1, '     Number of time steps'
      write (fileID1,*) 'Time, yr          Penetration depth, m'
      do  i=1,low+1
          write (fileID1, 9001) timeTPA(i,1), dsThick - penDepth(i,1)
      end do
      close (fileID1)
cccccccccccccccc
c END OF LINES ADDED TO ALWAYS CREATE DS THICKNESS VS TIME FILE
cccccccccccccccc
```

Edit Dsfailt.f. Removed the noted lines for comment.

```
cccccccccccccccc
c THESE LINES REMOVED TO ALWAYS CREATE DS THICKNESS VS TIME FILE
cccccccccccccccc
cc Interpolate penetration depths for TPA time steps
cccccccccccccccc
```

```
c          low = searchPosition(timeTPA,tf,TPATimeSteps)
cc Recall that b contains time in 1st column, and penetration depth in the second
c         do i=1,TimeSteps
c            x(i,1)=b(i,1)
c            y(i,1)=b(i,2)
c         end do
cc Interpolate penetration depth
c         do i=1,low+1
c            penDepth(i,1)=linearInterp(x,y,TimeSteps,timeTPA(i,1))
c         end do
cccccccccccccc
cc End of interpolated depths
cccccccccccccc
c
c          open (fileID1, file=fileOut1, status='unknown')
cccccccccccccc
cc Janetzke  --> introduce additional QA requirements (time file was created, etc)
cccccccccccccc
c         write (fileID1,*) 'GENERATING MODULE: DSfailt'
c         write (fileID1,*) 'Uniform corrosion of drip shield'
c      write (fileID1,*) 'Corrosion front penetration depth vs time'
c         write (fileID1,*) low+1, '     Number of time steps'
c         write (fileID1,*) 'Time, yr          Penetration depth, m'
c         do i=1,low+1
c            write (fileID1, 9001) timeTPA(i,1), penDepth(i,1)
c         end do
c         close(fileID1)
c
c     else
c
c         print *, ' '
c     print *, 'No failure of DS in ', nint(b(TimeSteps,1)), ' years'
c
c     end if
cccccccccccccc
```

April 3, 2002

Change Penetration Depth vs. Time output file to DS Thickness vs. Time output file.

Edit *DSfailt.inp*. Replace Penetration Depth filename with Thickness filename.

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{55}>vi DSfailt.inp

"DSfailt.inp" 15 lines, 885 characters
Input file for module DSfailt
This file is rewritten for each realization
================================================
fluoride.txt     fileIn, Input data file, fluoride concentration versus time
~~DSPenDepth.txt  fileOut1, Output data file 1, tracking penetration depth vs time~~
DSThickness.txt  fileOut1, Output data file 1, tracking thickness of the drip shield vs time
DSFailTime.txt   fileOut2, Output data file 2, failure time of the drip shield
1.0e-08          cr, m/yr, drip shield corrosion rate : DSCorrRate[m/yr]
15               dsThick, m, drip shield thickness : DripShieldThickness[m]
1.8              slope, dimensionless, slope of drip shield enhancing factor : TiCorrRateVsFluorideSlope
1.0e-04          minF, M, minimum fluoride concentration affecting the DS corrosion rate :
MinimumFluoride[Molar]
2.0e-03          maxF, M, maximum fluoride concentration affecting the DS corrosion rate :
MaximumFluoride[Molar]
TPATime.txt      fileTPAtime, Input file containing the TPA time steps
:wq
```

Edit *DSfailt.f*. Update fileOut1 description. Correct write to fileOut1 statement

```
/net/spock/home/cgrossman/dsfail/dsfail_rev1{57}>vi DSfailt.f
"DSfailt.f" 299 lines, 10560 characters
c Program Name:        DSfailt
c File Name:           DSfailt.f
c File Date:           01/28/02
c Release Version:     1.0
        :
        :
c=====================================================================
c NOMENCLATURE
c
c fileIn        : Input data file, fluoride concentration versus time
~~c fileOut1      : Output data file 1, tracking penetration depth vs time~~
c fileOut1      : Output data file 1, tracking thickness of drip shield vs time
c fileOut2      : Output data file 2, failure time of the drip shield
c cr            : m/yr, drip shield corrosion rate
c dsThick       : m, drip shield thickness
        :
        :
open (fileID1, file=fileOut1, status='unknown')
cccccccccccccccc
c Janetzke  --> introduce additional QA requirements (time file was created, etc)
cccccccccccccccc
write (fileID1,*) 'GENERATING MODULE: DSfailt'
write (fileID1,*) 'Uniform corrosion of drip shield'
~~write (fileID1,*) 'Corrosion front penetration depth vs time'~~
write (fileID1,*) 'Drip shield thickness vs time'
~~write (fileID1,*) low+1, '      Number of time steps'~~
write (fileID1,*) 'Number of time steps: ', low+1
~~write (fileID1,*) 'Time, yr            Penetration depth, m'~~
write (fileID1,*) 'Time, yr      Thickness, m'
do  i=1,low+1
    write (fileID1, 9001) timeTPA(i,1), dsThick-penDepth(i,1)
end do
close (fileID1)
cccccccccccccccc
c END OF LINES ADDED TO ALWAYS CREATE DS THICKNESS VS TIME FILE
cccccccccccccccc
:wq
```

April 4, 2002

Improve code formatting and readability

Edit *DSfailt.f.* Changed variable names to be more reflective of the values they represent to improve the readability. The following variable names were changed:

Previous Version	New Version
cr	CorrRate
dsThick	DSThick
a(1000000,2)	FluorideVsTime(1000000,2)
N/A	FluorideTime(1000000,1)
N/A	FluorideConc(1000000,1)
b(1000000,2)	Col 1: covered by FluorideTime(1000000,1)
	Col 2: covered by new PenDepth(1000000,1)
timeTPA(1000000,1)	TPATime(1000000,1)
x(1000000,1)	Eliminated. Covered by FluorideTime(1000000,1)
y(1000000,1)	Eliminated. Covered by PenDepth(1000000,1)
old PenDepth(1000000,1)	PenDepthVsTPATime(1000000,2)
N/A	PenDepth(1000000,1)
tf	FailureTime
flag	FailureFlag
low	FailureTimeStep
j	Eliminated.

Also updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

Edit *DSfailtime.f.* Changed variable names to be more reflective of the values they represent to improve the readability. The following variable names were changed:

Previous Version	New Version
a(1000000,2)	FluorideVsTime(1000000,2)
tf	FailureTime
b(1000000,2)	PenDepth(1000000,1)
	FluorideCorrRate(1000000,1)
flag	FailureFlag
c(1000000,1)	FluorideCorrRate(1000000,1)
cr	CorrRate
dsThick	DSThick
xo	Eliminated
offset	Offset
initialTime	InitialTime
initialPen	InitialPenDepth
initialCR	InitialCorrRate

Also updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

Edit *DSenhance.f.* Changed variable names to be more reflective of the values they represent to improve the readability. The following variable names were changed:

Previous Version	New Version

f	Fluoride

Also updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

Edit *int.f.* Changed variable names to be more reflective of the values they represent to improve the readability. The following variable names were changed:

Previous Version	New Version
a(1000000,2)	Integrand(1000000,2)
offset	Offset
b(1000000,2)	Integral(1000000,1)

Also updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

Edit *linearInterp.f.* Updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

Edit *searchPosition.f.* Changed variable names to be more reflective of the values they represent to improve the readability. The following variable names were changed:

Previous Version	New Version
dim	dimen

Also updated header and nomenclature comment sections. Added comment lines to delineate groups of statements that perform tasks.

April 5, 2002

Acceptance Testing of Dsfailt - Reading Input Data

Test 1. Does *DSfailt.e* input data from InputFile correctly?

Added following lines to *DSfailt.f* to output results

```
                :
                :
c---------- BEGIN OF READING INPUT FILE ------------------------------
      parameter (fileID1 = 7, InputFile = 'DSfailt.inp')

9001      format(2(1pe12.4,2x))

      open (fileID1, file = InputFile, status = 'old')
      do i = 1, 3
            read (fileID1, *) aline
      end do
      read (fileID1, *) fileIn
      read (fileID1, *) fileOut1
      read (fileID1, *) fileOut2
      read (fileID1, *) CorrRate
      read (fileID1, *) DSThick
      read (fileID1, *) slope
      read (fileID1, *) minF
      read (fileID1, *) maxF
      read (fileID1, *) fileTPAtime
      close(fileID1)

c     **Begin Error Checking**
c     **These Lines Can Be Deleted**
      print *, ' '
      print *, 'DATA FROM INPUTFILE'
      print *, 'fileIn = ', fileIn
      print *, 'fileOut1 = ', fileOut1
      print *, 'fileOut2 = ', fileOut2
      print *, 'CorrRate = ', CorrRate
      print *, 'DSThick = ', DSThick
      print *, 'slope = ', slope
      print *, 'minF = ', minF
      print *, 'maxF = ', maxF
      print *, 'fileTPAtime = ', fileTPAtime
c     **End Error Checking**
c---------- END OF READING INPUT FILE --------------------------------
                :
                :
```

Input file, *DSfailt.inp* contained the following data:

```
Input file for module DSfailt
This file is rewritten for each realization
===============================================
fluoride.txt    fileIn, Input data file, fluoride concentration versus time
DSThickness.txt fileOut1, Output data file 1, tracking thickness of the drip shield vs time
DSFailTime.txt  fileOut2, Output data file 2, failure time of the drip shield
1.0e-08         cr, m/yr, drip shield corrosion rate : DSCorrRate[m/yr]
0.015           dsThick, m, drip shield thickness : DripShieldThickness[m]
1.8             slope, dimensionless, slope of drip shield enhancing factor : TiCorrRateVsFluorideSlope
1.0e-04         minF, M, minimum fluoride concentration affecting the DS corrosion rate : MinimumFluoride[Molar]
2.0e-03         maxF, M, maximum fluoride concentration affecting the DS corrosion rate : MaximumFluoride[Molar]
TPATime.txt     fileTPAtime, Input file containing the TPA time steps
```

The output to the screen was as follows:

```
/net/spock/home/cgrossman/dsfail/dsfail_rev2{62}>DSfailt.e

 DATA FROM INPUTFILE
 fileIn = fluoride.txt
 fileOut1 = DSThickness.txt
 fileOut2 = DSFailTime.txt
 CorrRate =     1.0000000000000D-08
 DSThick =     1.5000000000000D-02
 slope =     1.8000000000000
 minF =     1.0000000000000D-04
 maxF =     2.0000000000000D-03
```

```
fileTPAtime = TPATime.txt

DS failure time =   6828 years
```

✓Dsfailt.e inputs data correctly.

Test 2. Does *DSfailt* input data from fileTPAtime correctly?
Added following lines to *DSfailt.f* to output results

```
                :
                :
c---------- BEGIN OF READ TPA TIME STEPS ----------------------------
      open (fileID1, file = fileTPAtime, status = 'old')
      read (fileID1,*) aline
      read (fileID1,*) TPATimeSteps
      read (fileID1,*) (TPATime(i,1),i=1,TPATimeSteps)
c     **Begin Error Checking**
c     **These Lines Can Be Deleted**
      print *, ' '
      print *, 'DATA FROM FILETPATIME'
      print *, 'TPATimeSteps = ', TPATimeSteps
      do i=1,TPATimeSteps
            print *, 'TPATime(', i, ',1) = ', TPATime(i,1)
      end do
c     **End Error Checking**
      close (fileID1)
c---------- END OF READ TPA TIME STEPS ------------------------------
                :
                :
```

Input file, *TPATime.txt*, contained the following data (left side of page)
Output from *DSfailt.e* is on right side of page.

```
TPA code time steps, yr. Input file to DSfail module
401     Number of time steps
0.00E+00
2.31E+00
4.67E+00
7.09E+00
9.57E+00
1.21E+01
1.47E+01
1.74E+01
2.01E+01
2.28E+01
2.57E+01
2.86E+01
3.16E+01
3.46E+01
3.78E+01
4.10E+01
4.42E+01
4.76E+01
5.10E+01
5.45E+01
5.81E+01
6.17E+01
6.55E+01
6.93E+01
7.33E+01
7.73E+01
8.14E+01
8.56E+01
9.00E+01
9.44E+01
9.89E+01
1.04E+02
1.08E+02
1.13E+02
1.18E+02
1.23E+02
```

```
/net/spock/home/cgrossman/dsfail/dsfail_rev2{68}>DSfailt
.e

 DATA FROM FILETPATIME
 TPATimeSteps =   401
 TPATime(  1,1) =   0.
 TPATime(  2,1) =     2.3100000000000
 TPATime(  3,1) =     4.6700000000000
 TPATime(  4,1) =     7.0900000000000
 TPATime(  5,1) =     9.5700000000000
 TPATime(  6,1) =     12.100000000000
 TPATime(  7,1) =     14.700000000000
 TPATime(  8,1) =     17.400000000000
 TPATime(  9,1) =     20.100000000000
 TPATime(  10,1) =     22.800000000000
 TPATime(  11,1) =     25.700000000000
 TPATime(  12,1) =     28.600000000000
 TPATime(  13,1) =     31.600000000000
 TPATime(  14,1) =     34.600000000000
 TPATime(  15,1) =     37.800000000000
 TPATime(  16,1) =     41.000000000000
 TPATime(  17,1) =     44.200000000000
 TPATime(  18,1) =     47.600000000000
 TPATime(  19,1) =     51.000000000000
 TPATime(  20,1) =     54.500000000000
 TPATime(  21,1) =     58.100000000000
 TPATime(  22,1) =     61.700000000000
 TPATime(  23,1) =     65.500000000000
 TPATime(  24,1) =     69.300000000000
 TPATime(  25,1) =     73.300000000000
 TPATime(  26,1) =     77.300000000000
 TPATime(  27,1) =     81.400000000000
 TPATime(  28,1) =     85.600000000000
 TPATime(  29,1) =     90.000000000000
 TPATime(  30,1) =     94.400000000000
 TPATime(  31,1) =     98.900000000000
 TPATime(  32,1) =    104.000000000000
 TPATime(  33,1) =     108.00000000000
```

```
1.28E+02
1.34E+02
1.39E+02
1.45E+02
1.50E+02
1.56E+02
1.62E+02
1.68E+02
1.74E+02
1.81E+02
1.87E+02
1.94E+02
2.01E+02
2.08E+02
2.15E+02
2.23E+02
2.30E+02
2.38E+02
2.46E+02
2.54E+02
2.62E+02
2.70E+02
2.79E+02
2.88E+02
2.97E+02
3.06E+02
3.16E+02
3.25E+02
3.35E+02
3.45E+02
3.56E+02
3.66E+02
3.77E+02
3.88E+02
4.00E+02
4.12E+02
4.24E+02
4.36E+02
4.48E+02
4.61E+02
4.74E+02
4.88E+02
5.01E+02
5.15E+02
5.30E+02
5.44E+02
5.59E+02
5.75E+02
5.91E+02
6.07E+02
6.23E+02
6.40E+02
6.58E+02
6.75E+02
6.93E+02
7.12E+02
7.31E+02
7.50E+02
7.70E+02
7.91E+02
8.11E+02
8.33E+02
8.54E+02
8.77E+02
9.00E+02
9.23E+02
9.47E+02
9.71E+02
9.96E+02
1.02E+03
1.05E+03
1.08E+03
1.10E+03
1.13E+03
1.16E+03
```

```
TPATime(  34,1) =     113.00000000000
TPATime(  35,1) =     118.00000000000
TPATime(  36,1) =     123.00000000000
TPATime(  37,1) =     128.00000000000
TPATime(  38,1) =     134.00000000000
TPATime(  39,1) =     139.00000000000
TPATime(  40,1) =     145.00000000000
TPATime(  41,1) =     150.00000000000
TPATime(  42,1) =     156.00000000000
TPATime(  43,1) =     162.00000000000
TPATime(  44,1) =     168.00000000000
TPATime(  45,1) =     174.00000000000
TPATime(  46,1) =     181.00000000000
TPATime(  47,1) =     187.00000000000
TPATime(  48,1) =     194.00000000000
TPATime(  49,1) =     201.00000000000
TPATime(  50,1) =     208.00000000000
TPATime(  51,1) =     215.00000000000
TPATime(  52,1) =     223.00000000000
TPATime(  53,1) =     230.00000000000
TPATime(  54,1) =     238.00000000000
TPATime(  55,1) =     246.00000000000
TPATime(  56,1) =     254.00000000000
TPATime(  57,1) =     262.00000000000
TPATime(  58,1) =     270.00000000000
TPATime(  59,1) =     279.00000000000
TPATime(  60,1) =     288.00000000000
TPATime(  61,1) =     297.00000000000
TPATime(  62,1) =     306.00000000000
TPATime(  63,1) =     316.00000000000
TPATime(  64,1) =     325.00000000000
TPATime(  65,1) =     335.00000000000
TPATime(  66,1) =     345.00000000000
TPATime(  67,1) =     356.00000000000
TPATime(  68,1) =     366.00000000000
TPATime(  69,1) =     377.00000000000
TPATime(  70,1) =     388.00000000000
TPATime(  71,1) =     400.00000000000
TPATime(  72,1) =     412.00000000000
TPATime(  73,1) =     424.00000000000
TPATime(  74,1) =     436.00000000000
TPATime(  75,1) =     448.00000000000
TPATime(  76,1) =     461.00000000000
TPATime(  77,1) =     474.00000000000
TPATime(  78,1) =     488.00000000000
TPATime(  79,1) =     501.00000000000
TPATime(  80,1) =     515.00000000000
TPATime(  81,1) =     530.00000000000
TPATime(  82,1) =     544.00000000000
TPATime(  83,1) =     559.00000000000
TPATime(  84,1) =     575.00000000000
TPATime(  85,1) =     591.00000000000
TPATime(  86,1) =     607.00000000000
TPATime(  87,1) =     623.00000000000
TPATime(  88,1) =     640.00000000000
TPATime(  89,1) =     658.00000000000
TPATime(  90,1) =     675.00000000000
TPATime(  91,1) =     693.00000000000
TPATime(  92,1) =     712.00000000000
TPATime(  93,1) =     731.00000000000
TPATime(  94,1) =     750.00000000000
TPATime(  95,1) =     770.00000000000
TPATime(  96,1) =     791.00000000000
TPATime(  97,1) =     811.00000000000
TPATime(  98,1) =     833.00000000000
TPATime(  99,1) =     854.00000000000
TPATime( 100,1) =     877.00000000000
TPATime( 101,1) =     900.00000000000
TPATime( 102,1) =     923.00000000000
TPATime( 103,1) =     947.00000000000
TPATime( 104,1) =     971.00000000000
TPATime( 105,1) =     996.00000000000
TPATime( 106,1) =     1020.0000000000
TPATime( 107,1) =     1050.0000000000
TPATime( 108,1) =     1080.0000000000
```

```
1.19E+03
1.22E+03
1.25E+03
1.28E+03
1.31E+03
1.35E+03
1.38E+03
1.42E+03
1.45E+03
1.49E+03
1.52E+03
1.56E+03
1.60E+03
1.64E+03
1.68E+03
1.72E+03
1.77E+03
1.81E+03
1.85E+03
1.90E+03
1.95E+03
1.99E+03
2.04E+03
2.09E+03
2.15E+03
2.20E+03
2.25E+03
2.31E+03
2.36E+03
2.42E+03
2.48E+03
2.54E+03
2.60E+03
2.66E+03
2.73E+03
2.80E+03
2.86E+03
2.93E+03
3.00E+03
3.08E+03
3.15E+03
3.23E+03
3.30E+03
3.38E+03
3.47E+03
3.55E+03
3.63E+03
3.72E+03
3.81E+03
3.90E+03
4.00E+03
4.09E+03
4.19E+03
4.29E+03
4.39E+03
4.50E+03
4.61E+03
4.72E+03
4.83E+03
4.95E+03
5.06E+03
5.18E+03
5.31E+03
5.43E+03
5.56E+03
5.70E+03
5.83E+03
5.97E+03
6.11E+03
6.26E+03
6.41E+03
6.56E+03
6.72E+03
6.88E+03
7.04E+03
```

```
TPATime(  109,1) =     1100.0000000000
TPATime(  110,1) =     1130.0000000000
TPATime(  111,1) =     1160.0000000000
TPATime(  112,1) =     1190.0000000000
TPATime(  113,1) =     1220.0000000000
TPATime(  114,1) =     1250.0000000000
TPATime(  115,1) =     1280.0000000000
TPATime(  116,1) =     1310.0000000000
TPATime(  117,1) =     1350.0000000000
TPATime(  118,1) =     1380.0000000000
TPATime(  119,1) =     1420.0000000000
TPATime(  120,1) =     1450.0000000000
TPATime(  121,1) =     1490.0000000000
TPATime(  122,1) =     1520.0000000000
TPATime(  123,1) =     1560.0000000000
TPATime(  124,1) =     1600.0000000000
TPATime(  125,1) =     1640.0000000000
TPATime(  126,1) =     1680.0000000000
TPATime(  127,1) =     1720.0000000000
TPATime(  128,1) =     1770.0000000000
TPATime(  129,1) =     1810.0000000000
TPATime(  130,1) =     1850.0000000000
TPATime(  131,1) =     1900.0000000000
TPATime(  132,1) =     1950.0000000000
TPATime(  133,1) =     1990.0000000000
TPATime(  134,1) =     2040.0000000000
TPATime(  135,1) =     2090.0000000000
TPATime(  136,1) =     2150.0000000000
TPATime(  137,1) =     2200.0000000000
TPATime(  138,1) =     2250.0000000000
TPATime(  139,1) =     2310.0000000000
TPATime(  140,1) =     2360.0000000000
TPATime(  141,1) =     2420.0000000000
TPATime(  142,1) =     2480.0000000000
TPATime(  143,1) =     2540.0000000000
TPATime(  144,1) =     2600.0000000000
TPATime(  145,1) =     2660.0000000000
TPATime(  146,1) =     2730.0000000000
TPATime(  147,1) =     2800.0000000000
TPATime(  148,1) =     2860.0000000000
TPATime(  149,1) =     2930.0000000000
TPATime(  150,1) =     3000.0000000000
TPATime(  151,1) =     3080.0000000000
TPATime(  152,1) =     3150.0000000000
TPATime(  153,1) =     3230.0000000000
TPATime(  154,1) =     3300.0000000000
TPATime(  155,1) =     3380.0000000000
TPATime(  156,1) =     3470.0000000000
TPATime(  157,1) =     3550.0000000000
TPATime(  158,1) =     3630.0000000000
TPATime(  159,1) =     3720.0000000000
TPATime(  160,1) =     3810.0000000000
TPATime(  161,1) =     3900.0000000000
TPATime(  162,1) =     4000.0000000000
TPATime(  163,1) =     4090.0000000000
TPATime(  164,1) =     4190.0000000000
TPATime(  165,1) =     4290.0000000000
TPATime(  166,1) =     4390.0000000000
TPATime(  167,1) =     4500.0000000000
TPATime(  168,1) =     4610.0000000000
TPATime(  169,1) =     4720.0000000000
TPATime(  170,1) =     4830.0000000000
TPATime(  171,1) =     4950.0000000000
TPATime(  172,1) =     5060.0000000000
TPATime(  173,1) =     5180.0000000000
TPATime(  174,1) =     5310.0000000000
TPATime(  175,1) =     5430.0000000000
TPATime(  176,1) =     5560.0000000000
TPATime(  177,1) =     5700.0000000000
TPATime(  178,1) =     5830.0000000000
TPATime(  179,1) =     5970.0000000000
TPATime(  180,1) =     6110.0000000000
TPATime(  181,1) =     6260.0000000000
TPATime(  182,1) =     6410.0000000000
TPATime(  183,1) =     6560.0000000000
```

```
7.21E+03
7.38E+03
7.55E+03
7.73E+03
7.91E+03
8.10E+03
8.29E+03
8.49E+03
8.69E+03
8.90E+03
9.11E+03
9.32E+03
9.54E+03
9.77E+03
1.00E+04
1.01E+04
1.02E+04
1.03E+04
1.05E+04
1.06E+04
1.07E+04
1.08E+04
1.10E+04
1.11E+04
1.12E+04
1.13E+04
1.15E+04
1.16E+04
1.17E+04
1.19E+04
1.20E+04
1.21E+04
1.23E+04
1.24E+04
1.26E+04
1.27E+04
1.29E+04
1.30E+04
1.32E+04
1.33E+04
1.35E+04
1.36E+04
1.38E+04
1.39E+04
1.41E+04
1.43E+04
1.44E+04
1.46E+04
1.48E+04
1.49E+04
1.51E+04
1.53E+04
1.55E+04
1.56E+04
1.58E+04
1.60E+04
1.62E+04
1.64E+04
1.66E+04
1.67E+04
1.69E+04
1.71E+04
1.73E+04
1.75E+04
1.77E+04
1.79E+04
1.81E+04
1.84E+04
1.86E+04
1.88E+04
1.90E+04
1.92E+04
1.94E+04
1.97E+04
1.99E+04
```

```
TPATime(  184,1) =     6720.0000000000
TPATime(  185,1) =     6880.0000000000
TPATime(  186,1) =     7040.0000000000
TPATime(  187,1) =     7210.0000000000
TPATime(  188,1) =     7380.0000000000
TPATime(  189,1) =     7550.0000000000
TPATime(  190,1) =     7730.0000000000
TPATime(  191,1) =     7910.0000000000
TPATime(  192,1) =     8100.0000000000
TPATime(  193,1) =     8290.0000000000
TPATime(  194,1) =     8490.0000000000
TPATime(  195,1) =     8690.0000000000
TPATime(  196,1) =     8900.0000000000
TPATime(  197,1) =     9110.0000000000
TPATime(  198,1) =     9320.0000000000
TPATime(  199,1) =     9540.0000000000
TPATime(  200,1) =     9770.0000000000
TPATime(  201,1) =    10000.0000000000
TPATime(  202,1) =    10100.0000000000
TPATime(  203,1) =    10200.0000000000
TPATime(  204,1) =    10300.0000000000
TPATime(  205,1) =    10500.0000000000
TPATime(  206,1) =     10600.000000000
TPATime(  207,1) =     10700.000000000
TPATime(  208,1) =     10800.000000000
TPATime(  209,1) =     11000.000000000
TPATime(  210,1) =     11100.000000000
TPATime(  211,1) =     11200.000000000
TPATime(  212,1) =     11300.000000000
TPATime(  213,1) =     11500.000000000
TPATime(  214,1) =     11600.000000000
TPATime(  215,1) =     11700.000000000
TPATime(  216,1) =     11900.000000000
TPATime(  217,1) =     12000.000000000
TPATime(  218,1) =     12100.000000000
TPATime(  219,1) =     12300.000000000
TPATime(  220,1) =     12400.000000000
TPATime(  221,1) =     12600.000000000
TPATime(  222,1) =     12700.000000000
TPATime(  223,1) =     12900.000000000
TPATime(  224,1) =     13000.000000000
TPATime(  225,1) =     13200.000000000
TPATime(  226,1) =     13300.000000000
TPATime(  227,1) =     13500.000000000
TPATime(  228,1) =     13600.000000000
TPATime(  229,1) =     13800.000000000
TPATime(  230,1) =     13900.000000000
TPATime(  231,1) =     14100.000000000
TPATime(  232,1) =     14300.000000000
TPATime(  233,1) =     14400.000000000
TPATime(  234,1) =     14600.000000000
TPATime(  235,1) =     14800.000000000
TPATime(  236,1) =     14900.000000000
TPATime(  237,1) =     15100.000000000
TPATime(  238,1) =     15300.000000000
TPATime(  239,1) =     15500.000000000
TPATime(  240,1) =     15600.000000000
TPATime(  241,1) =     15800.000000000
TPATime(  242,1) =     16000.000000000
TPATime(  243,1) =     16200.000000000
TPATime(  244,1) =     16400.000000000
TPATime(  245,1) =     16600.000000000
TPATime(  246,1) =     16700.000000000
TPATime(  247,1) =     16900.000000000
TPATime(  248,1) =     17100.000000000
TPATime(  249,1) =     17300.000000000
TPATime(  250,1) =     17500.000000000
TPATime(  251,1) =     17700.000000000
TPATime(  252,1) =     17900.000000000
TPATime(  253,1) =     18100.000000000
TPATime(  254,1) =     18400.000000000
TPATime(  255,1) =     18600.000000000
TPATime(  256,1) =     18800.000000000
TPATime(  257,1) =     19000.000000000
TPATime(  258,1) =     19200.000000000
```

```
2.01E+04
2.04E+04
2.06E+04
2.08E+04
2.11E+04
2.13E+04
2.16E+04
2.18E+04
2.21E+04
2.23E+04
2.26E+04
2.28E+04
2.31E+04
2.34E+04
2.36E+04
2.39E+04
2.42E+04
2.45E+04
2.48E+04
2.50E+04
2.53E+04
2.56E+04
2.59E+04
2.62E+04
2.65E+04
2.68E+04
2.71E+04
2.75E+04
2.78E+04
2.81E+04
2.84E+04
2.88E+04
2.91E+04
2.94E+04
2.98E+04
3.01E+04
3.05E+04
3.08E+04
3.12E+04
3.15E+04
3.19E+04
3.23E+04
3.26E+04
3.30E+04
3.34E+04
3.38E+04
3.42E+04
3.46E+04
3.50E+04
3.54E+04
3.58E+04
3.62E+04
3.66E+04
3.71E+04
3.75E+04
3.79E+04
3.84E+04
3.88E+04
3.92E+04
3.97E+04
4.02E+04
4.06E+04
4.11E+04
4.16E+04
4.21E+04
4.25E+04
4.30E+04
4.35E+04
4.40E+04
4.46E+04
4.51E+04
4.56E+04
4.61E+04
4.67E+04
4.72E+04
```

```
TPATime(  259,1) =     19400.000000000
TPATime(  260,1) =     19700.000000000
TPATime(  261,1) =     19900.000000000
TPATime(  262,1) =     20100.000000000
TPATime(  263,1) =     20400.000000000
TPATime(  264,1) =     20600.000000000
TPATime(  265,1) =     20800.000000000
TPATime(  266,1) =     21100.000000000
TPATime(  267,1) =     21300.000000000
TPATime(  268,1) =     21600.000000000
TPATime(  269,1) =     21800.000000000
TPATime(  270,1) =     22100.000000000
TPATime(  271,1) =     22300.000000000
TPATime(  272,1) =     22600.000000000
TPATime(  273,1) =     22800.000000000
TPATime(  274,1) =     23100.000000000
TPATime(  275,1) =     23400.000000000
TPATime(  276,1) =     23600.000000000
TPATime(  277,1) =     23900.000000000
TPATime(  278,1) =     24200.000000000
TPATime(  279,1) =     24500.000000000
TPATime(  280,1) =     24800.000000000
TPATime(  281,1) =     25000.000000000
TPATime(  282,1) =     25300.000000000
TPATime(  283,1) =     25600.000000000
TPATime(  284,1) =     25900.000000000
TPATime(  285,1) =     26200.000000000
TPATime(  286,1) =     26500.000000000
TPATime(  287,1) =     26800.000000000
TPATime(  288,1) =     27100.000000000
TPATime(  289,1) =     27500.000000000
TPATime(  290,1) =     27800.000000000
TPATime(  291,1) =     28100.000000000
TPATime(  292,1) =     28400.000000000
TPATime(  293,1) =     28800.000000000
TPATime(  294,1) =     29100.000000000
TPATime(  295,1) =     29400.000000000
TPATime(  296,1) =     29800.000000000
TPATime(  297,1) =     30100.000000000
TPATime(  298,1) =     30500.000000000
TPATime(  299,1) =     30800.000000000
TPATime(  300,1) =     31200.000000000
TPATime(  301,1) =     31500.000000000
TPATime(  302,1) =     31900.000000000
TPATime(  303,1) =     32300.000000000
TPATime(  304,1) =     32600.000000000
TPATime(  305,1) =     33000.000000000
TPATime(  306,1) =     33400.000000000
TPATime(  307,1) =     33800.000000000
TPATime(  308,1) =     34200.000000000
TPATime(  309,1) =     34600.000000000
TPATime(  310,1) =     35000.000000000
TPATime(  311,1) =     35400.000000000
TPATime(  312,1) =     35800.000000000
TPATime(  313,1) =     36200.000000000
TPATime(  314,1) =     36600.000000000
TPATime(  315,1) =     37100.000000000
TPATime(  316,1) =     37500.000000000
TPATime(  317,1) =     37900.000000000
TPATime(  318,1) =     38400.000000000
TPATime(  319,1) =     38800.000000000
TPATime(  320,1) =     39200.000000000
TPATime(  321,1) =     39700.000000000
TPATime(  322,1) =     40200.000000000
TPATime(  323,1) =     40600.000000000
TPATime(  324,1) =     41100.000000000
TPATime(  325,1) =     41600.000000000
TPATime(  326,1) =     42100.000000000
TPATime(  327,1) =     42500.000000000
TPATime(  328,1) =     43000.000000000
TPATime(  329,1) =     43500.000000000
TPATime(  330,1) =     44000.000000000
TPATime(  331,1) =     44600.000000000
TPATime(  332,1) =     45100.000000000
TPATime(  333,1) =     45600.000000000
```

```
4.78E+04
4.83E+04
4.89E+04
4.94E+04
5.00E+04
5.06E+04
5.12E+04
5.18E+04
5.24E+04
5.30E+04
5.36E+04
5.42E+04
5.48E+04
5.55E+04
5.61E+04
5.68E+04
5.74E+04
5.81E+04
5.88E+04
5.95E+04
6.02E+04
6.09E+04
6.16E+04
6.23E+04
6.30E+04
6.37E+04
6.45E+04
6.52E+04
6.60E+04
6.67E+04
6.75E+04
6.83E+04
6.91E+04
6.99E+04
7.07E+04
7.15E+04
7.24E+04
7.32E+04
7.41E+04
7.49E+04
7.58E+04
7.67E+04
7.76E+04
7.85E+04
7.94E+04
8.03E+04
8.12E+04
8.22E+04
8.31E+04
8.41E+04
8.51E+04
8.61E+04
8.71E+04
8.81E+04
8.91E+04
9.01E+04
9.12E+04
9.22E+04
9.33E+04
9.44E+04
9.55E+04
9.66E+04
9.77E+04
9.89E+04
1.00E+05
```

```
TPATime(  334,1) =     46100.000000000
TPATime(  335,1) =     46700.000000000
TPATime(  336,1) =     47200.000000000
TPATime(  337,1) =     47800.000000000
TPATime(  338,1) =     48300.000000000
TPATime(  339,1) =     48900.000000000
TPATime(  340,1) =     49400.000000000
TPATime(  341,1) =     50000.000000000
TPATime(  342,1) =     50600.000000000
TPATime(  343,1) =     51200.000000000
TPATime(  344,1) =     51800.000000000
TPATime(  345,1) =     52400.000000000
TPATime(  346,1) =     53000.000000000
TPATime(  347,1) =     53600.000000000
TPATime(  348,1) =     54200.000000000
TPATime(  349,1) =     54800.000000000
TPATime(  350,1) =     55500.000000000
TPATime(  351,1) =     56100.000000000
TPATime(  352,1) =     56800.000000000
TPATime(  353,1) =     57400.000000000
TPATime(  354,1) =     58100.000000000
TPATime(  355,1) =     58800.000000000
TPATime(  356,1) =     59500.000000000
TPATime(  357,1) =     60200.000000000
TPATime(  358,1) =     60900.000000000
TPATime(  359,1) =     61600.000000000
TPATime(  360,1) =     62300.000000000
TPATime(  361,1) =     63000.000000000
TPATime(  362,1) =     63700.000000000
TPATime(  363,1) =     64500.000000000
TPATime(  364,1) =     65200.000000000
TPATime(  365,1) =     66000.000000000
TPATime(  366,1) =     66700.000000000
TPATime(  367,1) =     67500.000000000
TPATime(  368,1) =     68300.000000000
TPATime(  369,1) =     69100.000000000
TPATime(  370,1) =     69900.000000000
TPATime(  371,1) =     70700.000000000
TPATime(  372,1) =     71500.000000000
TPATime(  373,1) =     72400.000000000
TPATime(  374,1) =     73200.000000000
TPATime(  375,1) =     74100.000000000
TPATime(  376,1) =     74900.000000000
TPATime(  377,1) =     75800.000000000
TPATime(  378,1) =     76700.000000000
TPATime(  379,1) =     77600.000000000
TPATime(  380,1) =     78500.000000000
TPATime(  381,1) =     79400.000000000
TPATime(  382,1) =     80300.000000000
TPATime(  383,1) =     81200.000000000
TPATime(  384,1) =     82200.000000000
TPATime(  385,1) =     83100.000000000
TPATime(  386,1) =     84100.000000000
TPATime(  387,1) =     85100.000000000
TPATime(  388,1) =     86100.000000000
TPATime(  389,1) =     87100.000000000
TPATime(  390,1) =     88100.000000000
TPATime(  391,1) =     89100.000000000
TPATime(  392,1) =     90100.000000000
TPATime(  393,1) =     91200.000000000
TPATime(  394,1) =     92200.000000000
TPATime(  395,1) =     93300.000000000
TPATime(  396,1) =     94400.000000000
TPATime(  397,1) =     95500.000000000
TPATime(  398,1) =     96600.000000000
TPATime(  399,1) =     97700.000000000
TPATime(  400,1) =     98900.000000000
TPATime(  401,1) =    100000.000000000

DS failure time =   6828 years
```

✓*DSfailt.e* inputs data correctly.

Test 3. Does *DSfailt.e* input data from fileIn correctly?
Added following lines to *DSfailt.f* to output results

```
                :
                :
c---------- BEGIN OF READ FLUORIDE CONCENTRATIONS ---------------------
      open (fileID1, file = fileIn, status = 'old')
      do i = 1, 4
             read (fileID1,*) aline
      end do
      read (fileID1,*) FluorideTimeSteps
c     **Begin Error Checking**
c     **These Lines Can Be Deleted**
      print *, ' '
      print *, 'DATA FROM FILEIN'
      print *, 'FluorideTimeSteps = ', FluorideTimeSteps
      print *, 'FluorideVsTime'
      print *, ' ', 'Time', 'Fluoride'
      print *, 'i', '(i,1)', '(i,2)'
c     **End Error Checking**
      read (fileID1,*) aline
      do i = 1, FluorideTimeSteps
              read (fileID1,*) FluorideTime(i,1), FluorideConc(i,1)
              FluorideVsTime(i,1) = FluorideTime(i,1)
              FluorideVsTime(i,2) = FluorideConc(i,1)
c             **Begin Error Checking**
c             **These Lines Can Be Deleted**
              print *, i, FluorideVsTime(i,1), FluorideVsTime(i,2)
c             **End Error Checking**
      end do
      close(fileID1)
c---------- END OF READ FLUORIDE CONCENTRATIONS -----------------------

                :
                :
```

Input file, *fluoride.txt*, contained the following data (left side of page)
Output from *DSfailt.e* is on right side of page.

```
Fake fluoride concentration
File provided as sample input file to the
DSfailt module
Osvaldo Pensado, 11-21-01
=============================================
103                     Number of time steps
Time, yr                Fluoride, M
0.0                     0.0
1.0                     0.0
1.1220184543019633      0.0007801596000000011
1.2589254117941673      0.0015212736000000027
1.4125375446227544      0.002224287600000001
1.5848931924611136      0.002890137600000001
1.7782794100389228      0.0035197500000000016
1.9952623149688797      0.004114041600000002
2.23872113856834        0.004673919600000003
2.51188643150958        0.005200281599999999
2.8183829312644537      0.005694015599999999
3.162277660168379       0.006155999999999999
3.548133892335755       0.0065871036
3.981071705534973       0.006988185600000001
4.466835921509632       0.0073600956
5.011872336272724       0.007703673600000001
5.623413251903491       0.00801975
6.309573444801933       0.008309145599999998
7.07945784384138        0.0085726716
7.943282347242816       0.008811129599999998
8.912509381337456       0.009025311599999999
10.                     0.009215999999999998
11.220184543019636      0.0093839676
12.589254117941675      0.0095299776
14.125375446227547      0.0096547836
15.848931924611142      0.009759129600000001
```

```
/net/spock/home/cgrossman/dsfail/dsfail_rev2{82}>DSfailt.e

 DATA FROM FILEIN
 FluorideTimeSteps =   103
 FluorideVsTime
  TimeFluoride
 i(i,1)(i,2)
   1  0.  0.
   2    1.0000000000000  0.
   3    1.1220184543020    7.8015960000000D-04
   4    1.2589254117942    1.5212736000000D-03
   5    1.4125375446228    2.2242876000000D-03
   6    1.5848931924611    2.8901376000000D-03
   7    1.7782794100389    3.5197500000000D-03
   8    1.9952623149689    4.1140416000000D-03
   9    2.2387211385683    4.6739196000000D-03
   10    2.5118864315096    5.2002816000000D-03
   11    2.8183829312645    5.6940156000000D-03
   12    3.1622776601684    6.1560000000000D-03
   13    3.5481338923358    6.5871036000000D-03
   14    3.9810717055350    6.9881856000000D-03
   15    4.4668359215096    7.3600956000000D-03
   16    5.0118723362727    7.7036736000000D-03
   17    5.6234132519035    8.0197500000000D-03
   18    6.3095734448019    8.3091456000000D-03
   19    7.0794578438414    8.5726716000000D-03
   20    7.9432823472428    8.8111296000000D-03
   21    8.9125093813375    9.0253116000000D-03
   22   10.0000000000000    9.2160000000000D-03
   23    11.220184543020    9.3839676000000D-03
   24    12.589254117942    9.5299776000000D-03
   25    14.125375446228    9.6547836000000D-03
   26    15.848931924611    9.7591296000000D-03
```

17.78279410038923	0.00984375
19.952623149688797	0.0099093696
22.3872113856834	0.0099567036
25.11886431509581	0.0099864576
28.18382931264455	0.0099993276
31.622776601683793	0.009996
35.48133892335755	0.009977151600000001
39.810717055349734	0.009943449600000001
44.668359215096324	0.0098955516
50.11872336272725	0.009834105599999999
56.23413251903491	0.009759750000000001
63.09573444801933	0.009673113600000002
70.79457843841381	0.009574815600000001
79.43282347242817	0.0094654656
89.12509381337459	0.0093456636
100.	0.009216
112.20184543019641	0.0090770556
125.89254117941675	0.0089294016
141.2537544622754	0.008773599600000001
158.48931924611142	0.0086102016
177.82794100389228	0.008439750000000001
199.52623149688807	0.0082627776
223.872113856834	0.0080798076
251.18864315095823	0.007891353599999998
281.8382931264455	0.0076979196
316.2277660168379	0.0075
354.81338923357566	0.0072980796
398.1071705534973	0.007092633600000001
446.6835921509635	0.0068841276
501.18723362727246	0.006673017600000002
562.341325190349	0.006459750000000002
630.9573444801937	0.006244761599999999
707.945784384138	0.006028479600000002
794.3282347242822	0.0058113216
891.2509381337459	0.005593695600000001
1000.	0.005376000000000004
1122.018454301964	0.0051586236
1258.9254117941675	0.0049419456
1412.5375446227554	0.004726335599999999975
1584.893192461114	0.004512153600000002
1778.2794100389228	0.004299750000000000015
1995.262314968881	0.004089465600000001
2238.72113856834	0.003881631600000002
2511.886431509582	0.0036765696000000013
2818.382931264455	0.003474591600000001
3162.2776601683795	0.003276000000000001
3548.1338923357566	0.003081087600000002
3981.0717055349733	0.002890137600000025
4466.835921509635	0.002703423600000001
5011.872336272725	0.0025212095999999993
5623.413251903491	0.002343750000000002
6309.573444801937	0.002171289599999999
7079.45784384138	0.0020040636000000023
7943.282347242822	0.0018422976000000025
8912.509381337459	0.0016862076000000025
10000.	0.0015359999999999996
11220.18454301963	0.001391871600000001
12589.254117941688	0.0012540095999999988
14125.375446227556	0.0011225915999999992
15848.93192461114	0.0009997855999999984
17782.794100389227	0.0008797500000000002
19952.62314968879	0.0007686336000000004
22387.211385683422	0.0006645756000000013
25118.864315095823	0.0005677056000000013
28183.82931264455	0.00047814359999999944
31622.776601683792	0.000396000000000003
35481.33892335753	0.0003213756000000023
39810.71705534977	0.0002543616000000004
44668.35921509635	0.00019503960000000098
50118.72336272725	0.00014348159999999944
56234.13251903491	0.00009974999999999957
63095.73444801943	0.00006389759999999911
70794.57843841388	0.00003596760000000088
79432.82347242822	0.000015993600000000497
89125.0938133746	3.99959999999977e-6

27	17.782794100389	9.8437500000000D-03
28	19.952623149689	9.9093696000000D-03
29	22.387211385683	9.9567036000000D-03
30	25.118864315096	9.9864576000000D-03
31	28.183829312645	9.9993276000000D-03
32	31.622776601684	9.9960000000000D-03
33	35.481338923358	9.9771516000000D-03
34	39.810717055350	9.9434496000000D-03
35	44.668359215096	9.8955516000000D-03
36	50.118723362727	9.8341056000000D-03
37	56.234132519035	9.7597500000000D-03
38	63.095734448019	9.6731136000000D-03
39	70.794578438414	9.5748156000000D-03
40	79.432823472428	9.4654656000000D-03
41	89.125093813375	9.3456636000000D-03
42	100.000000000000	9.2160000000000D-03
43	112.20184543020	9.0770556000000D-03
44	125.89254117942	8.9294016000000D-03
45	141.25375446228	8.7735996000000D-03
46	158.48931924611	8.6102016000000D-03
47	177.82794100389	8.4397500000000D-03
48	199.52623149689	8.2627776000000D-03
49	223.87211385683	8.0798076000000D-03
50	251.18864315096	7.8913536000000D-03
51	281.83829312645	7.6979196000000D-03
52	316.22776601684	7.5000000000000D-03
53	354.81338923358	7.2980796000000D-03
54	398.10717055350	7.0926336000000D-03
55	446.68359215096	6.8841276000000D-03
56	501.18723362727	6.6730176000000D-03
57	562.34132519035	6.4597500000000D-03
58	630.95734448019	6.2447616000000D-03
59	707.94578438414	6.0284796000000D-03
60	794.32823472428	5.8113216000000D-03
61	891.25093813375	5.5936956000000D-03
62	1000.00000000000	5.3760000000000D-03
63	1122.0184543020	5.1586236000000D-03
64	1258.9254117942	4.9419456000000D-03
65	1412.5375446228	4.7263356000000D-03
66	1584.8931924611	4.5121536000000D-03
67	1778.2794100389	4.2997500000000D-03
68	1995.2623149689	4.0894656000000D-03
69	2238.7211385683	3.8816316000000D-03
70	2511.8864315096	3.6765696000000D-03
71	2818.3829312645	3.4745916000000D-03
72	3162.2776601684	3.2760000000000D-03
73	3548.1338923358	3.0810876000000D-03
74	3981.0717055350	2.8901376000000D-03
75	4466.8359215096	2.7034236000000D-03
76	5011.8723362727	2.5212096000000D-03
77	5623.4132519035	2.3437500000000D-03
78	6309.5734448019	2.1712896000000D-03
79	7079.4578438414	2.0040636000000D-03
80	7943.2823472428	1.8422976000000D-03
81	8912.5093813375	1.6862076000000D-03
82	10000.0000000000	1.5360000000000D-03
83	11220.184543020	1.3918716000000D-03
84	12589.254117942	1.2540096000000D-03
85	14125.375446228	1.1225916000000D-03
86	15848.931924611	9.9778560000000D-04
87	17782.794100389	8.7975000000000D-04
88	19952.623149689	7.6863360000000D-04
89	22387.211385683	6.6457560000000D-04
90	25118.864315096	5.6770560000000D-04
91	28183.829312645	4.7814360000000D-04
92	31622.776601684	3.9600000000000D-04
93	35481.338923358	3.2137560000000D-04
94	39810.717055350	2.5436160000000D-04
95	44668.359215096	1.9503960000000D-04
96	50118.723362727	1.4348160000000D-04
97	56234.132519035	9.9750000000000D-05
98	63095.734448019	6.3897599999999D-05
99	70794.578438414	3.5967600000001D-05
100	79432.823472428	1.5993600000000D-05
101	89125.093813375	3.9995999999998D-06

```
100000.              0.0
1000000.             0.0
```

```
 102   100000.000000000  0.
 103   1000000.00000000  0.

DS failure time =   6828 years
```

✓*DSfailt.e* inputs data correctly.

April 8, 2002

Acceptance Testing of DSfailt - Calculating Thickness Vs Time and Failure Time

Test 1. Does *DSfailt.e* calculate Penetration Depth vs Time correctly?

Added following lines to *DSfailt.f* to output results

```
                :
                :
c---------- BEGIN OF CALCULATE FAILURE TIME & PENETRATION DEPTH -------
      call DSfailtime(FluorideVsTime, FluorideTimeSteps, FailureTime,
     &       PenDepth, FailureFlag)

c     **Begin Error Checking**
c     **These Lines Can Be Deleted**
      print *, ' '
      print *, 'PENETRATION DEPTHS FROM DSFAILTIME'
      do i = 1, FluorideTimeSteps
             print *, 'PenDepth(', i, ') = ', PenDepth(i,1)
      end do
c     **End Error Checking**
c---------- END OF CALCULATE FAILURE TIME & PENETRATION DEPTH ---------
                :
                :
```

The output to the screen was as follows:

```
/net/spock/home/cgrossman/dsfail/dsfail_rev2{7}>DSfa
ilt.e

 PENETRATION DEPTHS FROM DSFAILTIME
 PenDepth(  1) =   0.
 PenDepth(  2) =     1.0000000000000D-08
 PenDepth(  3) =     3.5232229415431D-08
 PenDepth(  4) =     1.5476998066229D-07
 PenDepth(  5) =     4.2664833750243D-07
 PenDepth(  6) =     8.0533456576481D-07
 PenDepth(  7) =     1.2302275022652D-06
 PenDepth(  8) =     1.7069652181212D-06
 PenDepth(  9) =     2.2418737331734D-06
 PenDepth(  10) =     2.8420509584252D-06
 PenDepth(  11) =     3.5154608810094D-06
 PenDepth(  12) =     4.2710392414591D-06
 PenDepth(  13) =     5.1188121055547D-06
 PenDepth(  14) =     6.0700289041265D-06
 PenDepth(  15) =     7.1373117061661D-06
 PenDepth(  16) =     8.3348227060136D-06
 PenDepth(  17) =     9.6784521470722D-06
 PenDepth(  18) =     1.1186029175683D-05
 PenDepth(  19) =     1.2877558423067D-05
 PenDepth(  20) =     1.4775485454622D-05
 PenDepth(  21) =     1.6904994608946D-05
 PenDepth(  22) =     1.9294343178703D-05
 PenDepth(  23) =     2.1975236367729D-05
 PenDepth(  24) =     2.4983247999830D-05
 PenDepth(  25) =     2.8358292561802D-05
 PenDepth(  26) =     3.2145154844425D-05
 PenDepth(  27) =     3.6394084209429D-05
 PenDepth(  28) =     4.1161461367989D-05
 PenDepth(  29) =     4.6510546518511D-05
 PenDepth(  30) =     5.2512318771029D-05
 PenDepth(  31) =     5.9246417996872D-05
 PenDepth(  32) =     6.6802201601368D-05
 PenDepth(  33) =     7.5279930242325D-05
```

THIS SIDE IS LEFT BLANK. RESULTS OF OFFLINE CALCULATIONS BELOW.

```
PenDepth(  34) =      8.4792098228043D-05
PenDepth(  35) =      9.5464926248438D-05
PenDepth(  36) =      1.0744003624691D-04
PenDepth(  37) =      1.2087633065750D-04
PenDepth(  38) =      1.3595210094361D-04
PenDepth(  39) =      1.5286739341744D-04
PenDepth(  40) =      1.7184666373300D-04
PenDepth(  41) =      1.9314175527624D-04
PenDepth(  42) =      2.1703524097380D-04
PenDepth(  43) =      2.4384417286407D-04
PenDepth(  44) =      2.7392428918508D-04
PenDepth(  45) =      3.0767473480479D-04
PenDepth(  46) =      3.4554335763103D-04
PenDepth(  47) =      3.8803265128107D-04
PenDepth(  48) =      4.3570642286667D-04
PenDepth(  49) =      4.8919727437189D-04
PenDepth(  50) =      5.4921499689707D-04
PenDepth(  51) =      6.1655598915549D-04
PenDepth(  52) =      6.9211382520045D-04
PenDepth(  53) =      7.7689111161002D-04
PenDepth(  54) =      8.7201279146720D-04
PenDepth(  55) =      9.7874107167116D-04
PenDepth(  56) =      1.0984921716559D-03
PenDepth(  57) =      1.2328551157618D-03
PenDepth(  58) =      1.3836128186229D-03
PenDepth(  59) =      1.5527657433612D-03
PenDepth(  60) =      1.7425584465168D-03
PenDepth(  61) =      1.9555093619492D-03
PenDepth(  62) =      2.1944442189248D-03
PenDepth(  63) =      2.4625335378275D-03
PenDepth(  64) =      2.7633347010375D-03
PenDepth(  65) =      3.1008391572347D-03
PenDepth(  66) =      3.4795253854971D-03
PenDepth(  67) =      3.9044183219975D-03
PenDepth(  68) =      4.3811560378535D-03
PenDepth(  69) =      4.9160645529056D-03
PenDepth(  70) =      5.5162417781574D-03
PenDepth(  71) =      6.1896517007417D-03
PenDepth(  72) =      6.9452300611913D-03
PenDepth(  73) =      7.7930029252870D-03
PenDepth(  74) =      8.7442197238588D-03
PenDepth(  75) =      9.8115025258984D-03
PenDepth(  76) =      1.1009013525746D-02
PenDepth(  77) =      1.2352642966804D-02
PenDepth(  78) =      1.3860219995416D-02
PenDepth(  79) =      1.5551749242799D-02
PenDepth(  80) =      1.7319258849676D-02
PenDepth(  81) =      1.9020815444144D-02
PenDepth(  82) =      2.0642352447437D-02
PenDepth(  83) =      2.2173871054595D-02
PenDepth(  84) =      2.3606211562479D-02
PenDepth(  85) =      2.4931309626349D-02
PenDepth(  86) =      2.6142457611478D-02
PenDepth(  87) =      2.7234562739038D-02
PenDepth(  88) =      2.8204391650823D-02
PenDepth(  89) =      2.9050788784613D-02
PenDepth(  90) =      2.9774853635496D-02
PenDepth(  91) =      3.0380059698098D-02
PenDepth(  92) =      3.0872295825380D-02
PenDepth(  93) =      3.1259809179276D-02
PenDepth(  94) =      3.1553028298987D-02
PenDepth(  95) =      3.1764245684414D-02
PenDepth(  96) =      3.1907142596983D-02
PenDepth(  97) =      3.1996283369193D-02
PenDepth(  98) =      3.2064899388483D-02
PenDepth(  99) =      3.2141887828387D-02
PenDepth(  100) =      3.2228270278727D-02
PenDepth(  101) =      3.2325192982136D-02
PenDepth(  102) =      3.2433942044003D-02
PenDepth(  103) =      4.1433942044003D-02

DS failure time =   6828 years
```

THIS SIDE IS LEFT BLANK. RESULTS OF OFFLINE CALCULATIONS BELOW.

Results of offline Microsoft® Excel 97 SR-2 (MSExcel) Spreadsheet, *Dsfailt Testing.xls*, calculations are as follows.

DSThick	0.015	
minF	1.00E-04	M
maxF	2.00E-03	M
Slope	1.8	
CorrRate	1.00E-08	m/yr
InitialCR	0	m/yr
InitialPen	0	m
InitialTime	0	yr
Offset	0	m

Fluoride Time yr	Fluoride Concen M	Enhance Factor	Enhance CorrRate m/yr	Pen Depth m	DS Thickness m
0	0	1	1.00E-08	0.0000000000E+00	0.015
1	0	1	1.00E-08	1.0000000000E-08	0.015
1.122018	0.00078	40.3581	4.04E-07	3.5232229415E-08	0.015
1.258925	0.001521	134.268	1.34E-06	1.5476998066E-07	0.015
1.412538	0.002224	219.712	2.20E-06	4.2664833750E-07	0.015
1.584893	0.00289	219.712	2.20E-06	8.0533456576E-07	0.015
1.778279	0.00352	219.712	2.20E-06	1.2302275023E-06	0.015
1.995262	0.004114	219.712	2.20E-06	1.7069652181E-06	0.015
2.238721	0.004674	219.712	2.20E-06	2.2418737332E-06	0.015
2.511886	0.0052	219.712	2.20E-06	2.8420509584E-06	0.015
2.818383	0.005694	219.712	2.20E-06	3.5154608810E-06	0.015
3.162278	0.006156	219.712	2.20E-06	4.2710392415E-06	0.015
3.548134	0.006587	219.712	2.20E-06	5.1188121056E-06	0.015
3.981072	0.006988	219.712	2.20E-06	6.0700289041E-06	0.015
4.466836	0.00736	219.712	2.20E-06	7.1373117062E-06	0.015
5.011872	0.007704	219.712	2.20E-06	8.3348227060E-06	0.015
5.623413	0.00802	219.712	2.20E-06	9.6784521471E-06	0.015
6.309573	0.008309	219.712	2.20E-06	1.1186029176E-05	0.015
7.079458	0.008573	219.712	2.20E-06	1.2877558423E-05	0.015
7.943282	0.008811	219.712	2.20E-06	1.4775485455E-05	0.015
8.912509	0.009025	219.712	2.20E-06	1.6904994609E-05	0.015
10	0.009216	219.712	2.20E-06	1.9294343179E-05	0.015
11.22018	0.009384	219.712	2.20E-06	2.1975236368E-05	0.015
12.58925	0.00953	219.712	2.20E-06	2.4983248000E-05	0.015
14.12538	0.009655	219.712	2.20E-06	2.8358292562E-05	0.015
15.84893	0.009759	219.712	2.20E-06	3.2145154844E-05	0.015
17.78279	0.009844	219.712	2.20E-06	3.6394084209E-05	0.015
19.95262	0.009909	219.712	2.20E-06	4.1161461368E-05	0.015
22.38721	0.009957	219.712	2.20E-06	4.6510546519E-05	0.015
25.11886	0.009986	219.712	2.20E-06	5.2512318771E-05	0.015
28.18383	0.009999	219.712	2.20E-06	5.9246417997E-05	0.015
31.62278	0.009996	219.712	2.20E-06	6.6802201601E-05	0.015
35.48134	0.009977	219.712	2.20E-06	7.5279930242E-05	0.015
39.81072	0.009943	219.712	2.20E-06	8.4792098228E-05	0.015
44.66836	0.009896	219.712	2.20E-06	9.5464926248E-05	0.015

Fail Time Interpolation

y = mx+b

y : Penetration Depth, m

x : Fluoride Time Steps, yr

m : Enhanced CorrRate, m/yr

b : Initial Offset, m

b	0
m**	2.1971E-06

FailTime = 6827

50.11872	0.009834	219.712	2.20E-06	1.0744003625E-04	0.015
56.23413	0.00976	219.712	2.20E-06	1.2087633066E-04	0.015
63.09573	0.009673	219.712	2.20E-06	1.3595210094E-04	0.015
70.79458	0.009575	219.712	2.20E-06	1.5286739342E-04	0.015
79.43282	0.009465	219.712	2.20E-06	1.7184666373E-04	0.015
89.12509	0.009346	219.712	2.20E-06	1.9314175528E-04	0.015
100	0.009216	219.712	2.20E-06	2.1703524097E-04	0.015
112.2018	0.009077	219.712	2.20E-06	2.4384417286E-04	0.015
125.8925	0.008929	219.712	2.20E-06	2.7392428919E-04	0.015
141.2538	0.008774	219.712	2.20E-06	3.0767473480E-04	0.015
158.4893	0.00861	219.712	2.20E-06	3.4554335763E-04	0.015
177.8279	0.00844	219.712	2.20E-06	3.8803265128E-04	0.015
199.5262	0.008263	219.712	2.20E-06	4.3570642287E-04	0.015
223.8721	0.00808	219.712	2.20E-06	4.8919727437E-04	0.015
251.1886	0.007891	219.712	2.20E-06	5.4921499690E-04	0.014
281.8383	0.007698	219.712	2.20E-06	6.1655598916E-04	0.014
316.2278	0.0075	219.712	2.20E-06	6.9211382520E-04	0.014
354.8134	0.007298	219.712	2.20E-06	7.7689111161E-04	0.014
398.1072	0.007093	219.712	2.20E-06	8.7201279147E-04	0.014
446.6836	0.006884	219.712	2.20E-06	9.7874107167E-04	0.014
501.1872	0.006673	219.712	2.20E-06	1.0984921717E-03	0.014
562.3413	0.00646	219.712	2.20E-06	1.2328551158E-03	0.014
630.9573	0.006245	219.712	2.20E-06	1.3836128186E-03	0.014
707.9458	0.006028	219.712	2.20E-06	1.5527657434E-03	0.013
794.3282	0.005811	219.712	2.20E-06	1.7425584465E-03	0.013
891.2509	0.005594	219.712	2.20E-06	1.9555093619E-03	0.013
1000	0.005376	219.712	2.20E-06	2.1944442189E-03	0.013
1122.018	0.005159	219.712	2.20E-06	2.4625335378E-03	0.013
1258.925	0.004942	219.712	2.20E-06	2.7633347010E-03	0.012
1412.538	0.004726	219.712	2.20E-06	3.1008391572E-03	0.012
1584.893	0.004512	219.712	2.20E-06	3.4795253855E-03	0.012
1778.279	0.0043	219.712	2.20E-06	3.9044183220E-03	0.011
1995.262	0.004089	219.712	2.20E-06	4.3811560379E-03	0.011
2238.721	0.003882	219.712	2.20E-06	4.9160645529E-03	0.010
2511.886	0.003677	219.712	2.20E-06	5.5162417782E-03	0.009
2818.383	0.003475	219.712	2.20E-06	6.1896517007E-03	0.009
3162.278	0.003276	219.712	2.20E-06	6.9452300612E-03	0.008
3548.134	0.003081	219.712	2.20E-06	7.7930029253E-03	0.007
3981.072	0.00289	219.712	2.20E-06	8.7442197239E-03	0.006
4466.836	0.002703	219.712	2.20E-06	9.8115025259E-03	0.005
5011.872	0.002521	219.712	2.20E-06	1.1009013526E-02	0.004
5623.413	0.002344	219.712	2.20E-06	1.2352642967E-02	0.003
6309.573	0.002171	219.712	2.20E-06	1.3860219995E-02	0.001
7079.458	0.002004	219.712	2.20E-06	1.5551749243E-02	0.000
7943.282	0.001842	189.517	1.90E-06	1.7319258850E-02	0.000
8912.509	0.001686	161.599	1.62E-06	1.9020815444E-02	0.000
10000	0.001536	136.617	1.37E-06	2.0642352447E-02	0.000
11220.18	0.001392	114.414	1.14E-06	2.2173871055E-02	0.000
12589.25	0.001254	94.8291	9.48E-07	2.3606211562E-02	0.000
14125.38	0.001123	77.6961	7.77E-07	2.4931309626E-02	0.000
15848.93	0.000998	62.8445	6.28E-07	2.6142457611E-02	0.000
17782.79	0.00088	50.101	5.01E-07	2.7234562739E-02	0.000
19952.62	0.000769	39.2912	3.93E-07	2.8204391651E-02	0.000
22387.21	0.000665	30.2399	3.02E-07	2.9050788785E-02	0.000
25118.86	0.000568	22.7731	2.28E-07	2.9774853635E-02	0.000
28183.83	0.000478	16.7188	1.67E-07	3.0380059698E-02	0.000

31622.78	0.000396	11.9083	1.19E-07	3.0872295825E-02	0.000
35481.34	0.000321	8.17755	8.18E-08	3.1259809179E-02	0.000
39810.72	0.000254	5.368	5.37E-08	3.1553028299E-02	0.000
44668.36	0.000195	3.32829	3.33E-08	3.1764245684E-02	0.000
50118.72	0.000143	1.91528	1.92E-08	3.1907142597E-02	0.000
56234.13	9.97E-05	1	1.00E-08	3.1996283369E-02	0.000
63095.73	6.39E-05	1	1.00E-08	3.2064899388E-02	0.000
70794.58	3.6E-05	1	1.00E-08	3.2141887828E-02	0.000
79432.82	1.6E-05	1	1.00E-08	3.2228270279E-02	0.000
89125.09	4.00E-06	1	1.00E-08	3.2325192982E-02	0.000
100000	0	1	1.00E-08	3.2433942044E-02	0.000
1000000	0	1	1.00E-08	4.1433942044E-02	0.000

The difference in failure times for *DSfailt.e* and MSExcel are due to minuscule differences in the resulting Penetration Depths. These are likely either due to rounding errors at the truncated decimal spot or the trapezoidal approximation of integration used in *int.f*, which is called by subroutine *DSfailtime.f*. Nonetheless, the differences result in a a one year difference in the calculation of the failure time over nearly 7,000 years. The table below contains the differences between the output and Excel results.

	DSfailt.e Output	Excel Results	Difference	% Diff
PenDepth(1) =	0.0000000000E+00	0.0000000000E+00	0.0000000000E+00	0.00E+00
PenDepth(2) =	1.0000000000E-08	1.0000000000E-08	0.0000000000E+00	0.00E+00
PenDepth(3) =	3.5232229415E-08	3.5232229415E-08	8.5365039215E-22	2.42E-12
PenDepth(4) =	1.5476998066E-07	1.5476998066E-07	9.3967717586E-21	6.07E-12
PenDepth(5) =	4.2664833750E-07	4.2664833750E-07	-4.0763460587E-21	-9.55E-13
PenDepth(6) =	8.0533456576E-07	8.0533456576E-07	2.5410988418E-21	3.16E-13
PenDepth(7) =	1.2302275023E-06	1.2302275023E-06	4.4469229731E-21	3.61E-13
PenDepth(8) =	1.7069652181E-06	1.7069652181E-06	3.3669559653E-20	1.97E-12
PenDepth(9) =	2.2418737332E-06	2.2418737332E-06	2.9646153154E-20	1.32E-12
PenDepth(10) =	2.8420509584E-06	2.8420509584E-06	2.2446373102E-20	7.90E-13
PenDepth(11) =	3.5154608810E-06	3.5154608810E-06	-4.4469229731E-20	-1.26E-12
PenDepth(12) =	4.2710392415E-06	4.2710392415E-06	5.5057141572E-20	1.29E-12
PenDepth(13) =	5.1188121056E-06	5.1188121056E-06	-4.1504614415E-20	-8.11E-13
PenDepth(14) =	6.0700289041E-06	6.0700289041E-06	-3.6422416732E-20	-6.00E-13
PenDepth(15) =	7.1373117062E-06	7.1373117062E-06	-2.2022856629E-20	-3.09E-13
PenDepth(16) =	8.3348227060E-06	8.3348227060E-06	-3.8963515574E-20	-4.67E-13
PenDepth(17) =	9.6784521471E-06	9.6784521471E-06	4.2351647363E-20	4.38E-13
PenDepth(18) =	1.1186029176E-05	1.1186029176E-05	-2.3716922523E-19	-2.12E-12
PenDepth(19) =	1.2877558423E-05	1.2877558423E-05	3.9641141932E-19	3.08E-12
PenDepth(20) =	1.4775485455E-05	1.4775485455E-05	-2.2531076397E-19	-1.52E-12
PenDepth(21) =	1.6904994609E-05	1.6904994609E-05	-1.9651164376E-19	-1.16E-12
PenDepth(22) =	1.9294343179E-05	1.9294343179E-05	3.2864878353E-19	1.70E-12
PenDepth(23) =	2.1975236368E-05	2.1975236368E-05	-3.4897757427E-19	-1.59E-12
PenDepth(24) =	2.4983248000E-05	2.4983248000E-05	2.7443867491E-19	1.10E-12
PenDepth(25) =	2.8358292562E-05	2.8358292562E-05	5.2854855909E-19	1.86E-12
PenDepth(26) =	3.2145154844E-05	3.2145154844E-05	-2.0328790734E-19	-6.32E-13
PenDepth(27) =	3.6394084209E-05	3.6394084209E-05	-8.8091426514E-20	-2.42E-13
PenDepth(28) =	4.1161461368E-05	4.1161461368E-05	2.0328790734E-19	4.94E-13
PenDepth(29) =	4.6510546519E-05	4.6510546519E-05	1.6940658945E-19	3.64E-13
PenDepth(30) =	5.2512318771E-05	5.2512318771E-05	1.0164395367E-19	1.94E-13

PenDepth(31) =	5.9246417997E-05	5.9246417997E-05	4.3368086899E-19	7.32E-13
PenDepth(32) =	6.6802201601E-05	6.6802201601E-05	4.2012834184E-19	6.29E-13
PenDepth(33) =	7.5279930242E-05	7.5279930242E-05	4.7433845046E-19	6.30E-13
PenDepth(34) =	8.4792098228E-05	8.4792098228E-05	5.2854855909E-19	6.23E-13
PenDepth(35) =	9.5464926248E-05	9.5464926248E-05	-3.5236570606E-19	-3.69E-13
PenDepth(36) =	1.0744003625E-04	1.0744003625E-04	-3.5236570606E-18	-3.28E-12
PenDepth(37) =	1.2087633066E-04	1.2087633066E-04	1.2874900798E-18	1.07E-12
PenDepth(38) =	1.3595210094E-04	1.3595210094E-04	4.8789097762E-19	3.59E-13
PenDepth(39) =	1.5286739342E-04	1.5286739342E-04	-3.1441863002E-18	-2.06E-12
PenDepth(40) =	1.7184666373E-04	1.7184666373E-04	5.9631119487E-19	3.47E-13
PenDepth(41) =	1.9314175528E-04	1.9314175528E-04	8.6736173799E-19	4.49E-13
PenDepth(42) =	2.1703524097E-04	2.1703524097E-04	-3.8489177123E-18	-1.77E-12
PenDepth(43) =	2.4384417286E-04	2.4384417286E-04	-6.2341624918E-19	-2.56E-13
PenDepth(44) =	2.7392428919E-04	2.7392428919E-04	5.6378512969E-18	2.06E-12
PenDepth(45) =	3.0767473480E-04	3.0767473480E-04	-1.8431436932E-18	-5.99E-13
PenDepth(46) =	3.4554335763E-04	3.4554335763E-04	8.1315162936E-19	2.35E-13
PenDepth(47) =	3.8803265128E-04	3.8803265128E-04	2.0057740191E-18	5.17E-13
PenDepth(48) =	4.3570642287E-04	4.3570642287E-04	2.7647155398E-18	6.35E-13
PenDepth(49) =	4.8919727437E-04	4.8919727437E-04	4.5536491244E-18	9.31E-13
PenDepth(50) =	5.4921499690E-04	5.4921499690E-04	3.9031278209E-18	7.11E-13
PenDepth(51) =	6.1655598916E-04	6.1655598916E-04	-2.8189256485E-18	-4.57E-13
PenDepth(52) =	6.9211382520E-04	6.9211382520E-04	-2.8189256485E-18	-4.07E-13
PenDepth(53) =	7.7689111161E-04	7.7689111161E-04	-2.4936649967E-18	-3.21E-13
PenDepth(54) =	8.7201279147E-04	8.7201279147E-04	-2.0599841277E-18	-2.36E-13
PenDepth(55) =	9.7874107167E-04	9.7874107167E-04	0.0000000000E+00	0.00E+00
PenDepth(56) =	1.0984921717E-03	1.0984921717E-03	-1.2576745201E-17	-1.14E-12
PenDepth(57) =	1.2328551158E-03	1.2328551158E-03	3.5561831258E-17	2.88E-12
PenDepth(58) =	1.3836128186E-03	1.3836128186E-03	2.7321894747E-17	1.97E-12
PenDepth(59) =	1.5527657434E-03	1.5527657434E-03	-9.1072982489E-18	-5.87E-13
PenDepth(60) =	1.7425584465E-03	1.7425584465E-03	2.6454533009E-17	1.52E-12
PenDepth(61) =	1.9555093619E-03	1.9555093619E-03	3.1658703437E-17	1.62E-12
PenDepth(62) =	2.1944442189E-03	2.1944442189E-03	-1.6046192153E-17	-7.31E-13
PenDepth(63) =	2.4625335378E-03	2.4625335378E-03	1.6046192153E-17	6.52E-13
PenDepth(64) =	2.7633347010E-03	2.7633347010E-03	-2.1684043450E-17	-7.85E-13
PenDepth(65) =	3.1008391572E-03	3.1008391572E-03	3.9031278209E-18	1.26E-13
PenDepth(66) =	3.4795253855E-03	3.4795253855E-03	3.0791341699E-17	8.85E-13
PenDepth(67) =	3.9044183220E-03	3.9044183220E-03	4.2067044292E-17	1.08E-12
PenDepth(68) =	4.3811560379E-03	4.3811560379E-03	4.8572257327E-17	1.11E-12
PenDepth(69) =	4.9160645529E-03	4.9160645529E-03	-3.2959746044E-17	-6.70E-13
PenDepth(70) =	5.5162417782E-03	5.5162417782E-03	-3.9031278209E-17	-7.08E-13
PenDepth(71) =	6.1896517007E-03	6.1896517007E-03	0.0000000000E+00	0.00E+00
PenDepth(72) =	6.9452300612E-03	6.9452300612E-03	-7.8062556419E-18	-1.12E-13
PenDepth(73) =	7.7930029253E-03	7.7930029253E-03	0.0000000000E+00	0.00E+00
PenDepth(74) =	8.7442197239E-03	8.7442197239E-03	0.0000000000E+00	0.00E+00
PenDepth(75) =	9.8115025259E-03	9.8115025259E-03	1.5612511284E-17	1.59E-13
PenDepth(76) =	1.1009013526E-02	1.1009013526E-02	1.0061396161E-16	9.14E-13
PenDepth(77) =	1.2352642967E-02	1.2352642967E-02	-4.1980308119E-16	-3.40E-12
PenDepth(78) =	1.3860219995E-02	1.3860219995E-02	4.9786563761E-16	3.59E-12
PenDepth(79) =	1.5551749243E-02	1.5551749243E-02	1.3530843113E-16	8.70E-13
PenDepth(80) =	1.7319258850E-02	1.7319258850E-02	3.4694469520E-16	2.00E-12
PenDepth(81) =	1.9020815444E-02	1.9020815444E-02	-7.9797279895E-17	-4.20E-13
PenDepth(82) =	2.0642352447E-02	2.0642352447E-02	-3.8163916471E-17	-1.85E-13
PenDepth(83) =	2.2173871055E-02	2.2173871055E-02	-3.0531133177E-16	-1.38E-12
PenDepth(84) =	2.3606211562E-02	2.3606211562E-02	3.6429192996E-16	1.54E-12

PenDepth(85) =	2.4931309626E-02	2.4931309626E-02	-1.5959455979E-16	-6.40E-13
PenDepth(86) =	2.6142457611E-02	2.6142457611E-02	3.0184188482E-16	1.15E-12
PenDepth(87) =	2.7234562739E-02	2.7234562739E-02	2.4633073359E-16	9.04E-13
PenDepth(88) =	2.8204391651E-02	2.8204391651E-02	5.8980598183E-17	2.09E-13
PenDepth(89) =	2.9050788785E-02	2.9050788785E-02	5.0653925499E-16	1.74E-12
PenDepth(90) =	2.9774853635E-02	2.9774853635E-02	5.6205040622E-16	1.89E-12
PenDepth(91) =	3.0380059698E-02	3.0380059698E-02	9.0205620751E-17	2.97E-13
PenDepth(92) =	3.0872295825E-02	3.0872295825E-02	2.7755575616E-17	8.99E-14
PenDepth(93) =	3.1259809179E-02	3.1259809179E-02	0.0000000000E+00	0.00E+00
PenDepth(94) =	3.1553028299E-02	3.1553028299E-02	4.5796699766E-16	1.45E-12
PenDepth(95) =	3.1764245684E-02	3.1764245684E-02	5.8286708793E-16	1.83E-12
PenDepth(96) =	3.1907142597E-02	3.1907142597E-02	8.3266726847E-17	2.61E-13
PenDepth(97) =	3.1996283369E-02	3.1996283369E-02	6.2450045135E-17	1.95E-13
PenDepth(98) =	3.2064899388E-02	3.2064899388E-02	2.0816681712E-16	6.49E-13
PenDepth(99) =	3.2141887828E-02	3.2141887828E-02	2.6367796835E-16	8.20E-13
PenDepth(100) =	3.2228270279E-02	3.2228270279E-02	1.2490009027E-16	3.88E-13
PenDepth(101) =	3.2325192982E-02	3.2325192982E-02	-3.4000580129E-16	-1.05E-12
PenDepth(102) =	3.2433942044E-02	3.2433942044E-02	4.0939474033E-16	1.26E-12
PenDepth(103) =	4.1433942044E-02	4.1433942044E-02	4.0245584643E-16	9.71E-13

✓*DSfailt.e* calculates penetration depth and DS failure time adequately.

April 9, 2002

Acceptance Testing of subroutine *int* - Trapezoidal Approximation Error.

Purpose - To see how accurate the int subroutine approximates an integral with trapezoidal approximation.

Edit *DSfailt.f*. Added the following lines and commented out all other lines after parameter declarations.

```
c       **Begin Error Checking**
c       **These Lines Can Be Deleted**
        double precision Offset
        integer j
        external Int

        parameter (fileID1 = 7, InputFile = 'normal.txt')

        Offset = 0
        open (fileID1, file = InputFile, status = 'old')
        do i = 1, 4
               read (fileID1, *) aline
        end do
        read (fileID1, *) FluorideTimeSteps
        read (fileID1, *) aline
        do i = 1, FluorideTimeSteps
               read (fileID1, *) (FluorideVsTime(i,j), j = 1, 2)
        end do
        close (fileID1)
        call Int(FluorideVsTime, FluorideTimeSteps, Offset, FluorideTime)
        print *, ' '
        print *, 'ERROR CHECK:'
        print *, 'INTEGRATION OF STANDARD NORMAL DISTRIBUTION'
        do i = 1, FluorideTimeSteps
               print *, FluorideVsTime(i,1), FluorideVsTime(i,2),
      &                FluorideTime(i,1)
        end do
        end
c       **End Error Checking**
```

Generated one-half of the standard normal distribution curve file in *normal.txt* using the following formula in MSExcel.

$$pdf = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma}$$ where μ = mean = 0 and σ = standard deviation = 1

Recall that...

$$0.5 = \int_0^{+\infty} pdf_{stdnormal}$$

The output of *DSFailt.e* are as follows (The 1st column = x; 2nd column = pdf (as calculated in MSExcel); 3rd column = integral of pdf from int subroutine):

```
c       end
/net/spock/home/cgrossman/dsfail/dsfail_rev2{14}>DSfailt.e

 ERROR CHECK:
 INTEGRATION OF STANDARD NORMAL DISTRIBUTION
   0.   0.39894228040143  0.
     1.0000000000000D-01   0.39695254747701    3.9794741393922D-02
    0.20000000000000   0.39104269397546    7.9194503466546D-02
    0.30000000000000   0.38138781546052   0.11781602893834
    0.40000000000000   0.36827014030332   0.15529892672654
    0.50000000000000   0.35206532676430   0.19131570007992
    0.60000000000000   0.33322460289180   0.22558019656272
    0.70000000000000   0.31225393336676   0.25785412337565
    0.80000000000000   0.28969155276148   0.28795139768206
    0.90000000000000   0.26608524989875   0.31574023781507
     1.0000000000000   0.24197072451914   0.34114303653597
     1.1000000000000   0.21785217703255   0.36413418161355
     1.2000000000000   0.19418605498321   0.38473609321434
     1.3000000000000   0.17136859204781   0.40301382556589
     1.4000000000000   0.14972746563574   0.41906862845007
     1.5000000000000   0.12951759566589   0.43303088151515
     1.6000000000000   0.11092083467946   0.44505280303242
     1.7000000000000    9.4049077376887D-02   0.45530129863524
     1.8000000000000    7.8950158300894D-02   0.46395126041913
     1.9000000000000    6.5615814774676D-02   0.47117955907291
     2.0000000000000    5.3990966513188D-02   0.47715989813730
     2.1000000000000    4.3983595980427D-02   0.48205862626198
     2.2000000000000    3.5474592846231D-02   0.48603153570331
     2.3000000000000    2.8327037741601D-02   0.48922161723270
     2.4000000000000    2.2394530294843D-02   0.49175769563453
     2.5000000000000    1.7528300493568D-02   0.49375383717395
     2.6000000000000    1.3582969233686D-02   0.49530940066031
     2.7000000000000    1.0420934814423D-02   0.49650959586271
     2.8000000000000    7.9154515829800D-03   0.49742641518258
     2.9000000000000    5.9525324197758D-03   0.49811981438272
     3.0000000000000    4.4318484119380D-03   0.49863903342431
     3.1000000000000    3.2668190561999D-03   0.49902396679771
     3.2000000000000    2.3840882014648D-03   0.49930651216060
     3.3000000000000    1.7225689390537D-03   0.49951184501762
     3.4000000000000    1.2322191684730D-03   0.49965958442300
     3.5000000000000    8.7268269504576D-04   0.49976482951618
     3.6000000000000    6.1190193011377D-04   0.49983905874743
     3.7000000000000    4.2478027055075D-04   0.49989089285747
     3.8000000000000    2.9194692579146D-04   0.49992672921728
     3.9000000000000    1.9865547139277D-04   0.49995125933714
     4.0000000000000    1.3383022576488D-04   0.49996788362200
     4.1000000000000    8.9261657177133D-05   0.49997903821615
     4.2000000000000    5.8943067756540D-05   0.49998644845240
     4.3000000000000    3.8535196742087D-05   0.49999132236562
     4.4000000000000    2.4942471290053D-05   0.49999449624902
     4.5000000000000    1.5983741106905D-05   0.49999654255964
     4.6000000000000    1.0140852065487D-05   0.49999784878930
     4.7000000000000    6.3698251788671D-06   0.49999867432316
     4.8000000000000    3.9612990910321D-06   0.49999919087938
     4.9000000000000    2.4389607458933D-06   0.49999951089237
     5.0000000000000    1.4867195147343D-06   0.49999970717638
     5.1000000000000    8.9724351623833D-07   0.49999982637453
```

```
    5.2000000000000    5.3610353446976D-07   0.49999989804189
    5.3000000000000    3.1713492167160D-07   0.49999994070381
    5.4000000000000    1.8573618445552D-07   0.49999996584736
    5.5000000000000    1.0769760042543D-07   0.49999998051905
    5.6000000000000    6.1826205001659D-08   0.49999998899524
    5.7000000000000    3.5139550948204D-08   0.49999999384353
    5.8000000000000    1.9773196406245D-08   0.49999999658917
    5.9000000000000    1.1015763624682D-08   0.49999999812862
    6.0000000000000    6.0758828498233D-09   0.49999999898320
    6.1000000000000    3.3178842435473D-09   0.49999999945289
    6.2000000000000    1.7937839079641D-09   0.49999999970847
    6.3000000000000    9.6014333703123D-10   0.49999999984617
    6.4000000000000    5.0881402816449D-10   0.49999999991961
    6.5000000000000    2.6695566147628D-10   0.49999999995840
    6.6000000000000    1.3866799941653D-10   0.49999999997868
    6.7000000000000    7.1313281239961D-11   0.49999999998918
    6.8000000000000    3.6309615017918D-11   0.49999999999456
    6.9000000000000    1.8303322170155D-11   0.49999999999729
    7.0000000000000    9.1347204083646D-12   0.49999999999867
    7.1000000000000    4.5135436772055D-12   0.49999999999935
    7.2000000000000    2.2079899631371D-12   0.49999999999969
    7.3000000000000    1.0693837871542D-12   0.49999999999985
    7.4000000000000    5.1277536367965D-13   0.49999999999993
    7.5000000000000    2.4343205330290D-13   0.49999999999997
    7.6000000000000    1.1441564901801D-13   0.49999999999998
    7.7000000000000    5.3241483722529D-14   0.49999999999999
    7.8000000000000    2.4528552856964D-14   0.50000000000000
    7.9000000000000    1.1187956214351D-14   0.50000000000000
    8.0000000000000    5.0522710835369D-15   0.50000000000000
    8.1000000000000    2.2588094031543D-15   0.50000000000000
    8.2000000000000    9.9983787484972D-16   0.50000000000000
    8.3000000000000    4.3816394355093D-16   0.50000000000000
    8.4000000000000    1.9010815379079D-16   0.50000000000000
    8.5000000000000    8.1662356316696D-17   0.50000000000000
    8.6000000000000    3.4729627485662D-17   0.50000000000000
    8.7000000000000    1.4622963575007D-17   0.50000000000000
    8.8000000000000    6.0957581295624D-18   0.50000000000000
    8.9000000000000    2.5158057769513D-18   0.50000000000000
    9.0000000000000    1.0279773571669D-18   0.50000000000000
          :                  :                    :
```

This section was removed. Result did not change for these values.

```
          :                  :                    :
    37.000000000000    2.1200065515246-298   0.50000000000000
    37.100000000000    5.2152621988320-300   0.50000000000000
    37.200000000000    1.2702001138306-301   0.50000000000000
    37.300000000000    3.0628462906958-303   0.50000000000000
    37.400000000000    7.3119853455048-305   0.50000000000000
    37.500000000000    1.7282337322841-306   0.50000000000000
    37.600000000000    4.0441448093482-308   0.50000000000000
    37.700000000000  0.   0.50000000000000
    37.800000000000  0.   0.50000000000000
    37.900000000000  0.   0.50000000000000
    38.000000000000  0.   0.50000000000000
Note: IEEE floating-point exception flags raised:
   Inexact;  Underflow;
See the Numerical Computation Guide, ieee_flags(3M)
```

The *int* subroutine can carry out the calculations to the 14th decimal place.
✓Int.f is a good approximation of integration.

April 10, 2002

Merge subroutine and function code files into main file, dsfailt.f, to create stand-alone code.

Change *dsfailt.f* to read fluoride concentrations vs. TPA time steps.
It is anticipated that the fluoride concentrations will be based on TPA time steps when DSFAIL subroutine begins. Therefore, the stand-alone code, *dsfailt.f*, will not need to convert to TPA time steps, making parts of the stand-alone code unneeded. After walk-through with R. Janetzke, decided to change vector declarations to conserve memory blocks. Will reduce array declarations from 1000000 to the maximum number of TPA time steps allowable through the creation of a parameter, MaxTimeSteps.
Edit *dsfailt.f*

```
 program DSfail

      implicit none

      integer fileID1, ~~Fluoride~~TimeSteps, ~~TPATimeSteps,~~
     &        FailureFlag, FailureTimeStep, MaxTimeSteps
      double precision CorrRate, DSThick, slope, minF, maxF,
     &        FailureTime

      parameter (MaxTimeSteps = 401)

      integer i
      double precision ~~FluorideVsTime(1000000,2)~~,
     &       ~~Fluoride~~Time(MaxTimeSteps~~1000000,1~~), Fluoride~~Conc~~(MaxTimeSteps~~1000000,1~~),
     &       PenDepth(MaxTimeSteps~~1000000,1~~)~~, TPATime(1000000,1),~~
     &       ~~PenDepthVsTPATime(1000000,2)~~

      character fileIn*50, fileOut1*50, fileOut2*50, aline*50,
     &       InputFile*50, fileTPAtime*50

      external DSfailtime, linearInterp, searchPosition
      integer searchPosition
      double precision linearInterp

      common /DS1/ CorrRate, DSThick
      common /DS2/ slope, minF, maxF
      common /DS3/ ~~TPA~~Time, ~~TPA~~TimeSteps
                        :
                        :
~~c---------- BEGIN OF READ TPA TIME STEPS ----------~~
~~      open (fileID1, file = fileTPAtime, status = 'old')~~
~~      read (fileID1,*) aline~~
~~      read (fileID1,*) TPATimeSteps~~
~~      read (fileID1,*) (TPATime(i,1),i=1,TPATimeSteps)~~
~~c     **Begin Error Checking**~~
~~c     **These Lines Can Be Deleted**~~
~~c      print *, ' '~~
~~c      print *, 'DATA FROM FILETPATIME'~~
~~c      print *, 'TPATimeSteps = ', TPATimeSteps~~
~~c      do i=1,TPATimeSteps~~
~~c            print *, 'TPATime(', i, ',1) = ', TPATime(i,1)~~
~~c      end do~~
~~c     **End Error Checking**~~
~~      close (fileID1)~~
~~c---------- END OF READ TPA TIME STEPS ----------~~


c---------- BEGIN OF READ FLUORIDE CONCENTRATIONS ----------
      open (fileID1, file = fileIn, status = 'old')
      do i = 1, 4
            read (fileID1,*) aline
      end do
      read (fileID1,*) ~~Fluoride~~TimeSteps
c     **Begin Error Checking**
c     **These Lines Can Be Deleted**
c      print *, ' '
c      print *, 'DATA FROM FILEIN'
c      print *, 'FluorideTimeSteps = ', FluorideTimeSteps
```

```
c       print *, 'FluorideVsTime'
c       print *, ' ', 'Time', 'Fluoride'
c       print *, 'i', '(i,1)', '(i,2)'
c      **End Error Checking**
       read (fileID1,*) aline
       do i = 1, FluorideTimeSteps
               read (fileID1,*) FluorideTime(i,1), FluorideConc(i,1)
               FluorideVsTime(i,1) = FluorideTime(i,1)
               FluorideVsTime(i,2) = FluorideConc(i,1)
c              **Begin Error Checking**
c              **These Lines Can Be Deleted**
c               print *, i, FluorideVsTime(i,1), FluorideVsTime(i,2)
c              **End Error Checking**
       end do
       close(fileID1)
c---------- END OF READ FLUORIDE CONCENTRATIONS -----------------------


c---------- BEGIN OF CALCULATE FAILURE TIME & PENETRATION DEPTH -------
       call DSfailtime(FluorideVsTime, FluorideTimeSteps, FailureTime,
     &        PenDepth, FailureFlag)

c      **Begin Error Checking**
c      **These Lines Can Be Deleted**
c       print *, ' '
c       print *, 'PENETRATION DEPTHS FROM DSFAILTIME'
c       do i = 1, FluorideTimeSteps
c               print *, 'PenDepth(', i, ') = ', PenDepth(i,1)
c       end do
c      **End Error Checking**
c---------- END OF CALCULATE FAILURE TIME & PENETRATION DEPTH ---------


c---------- BEGIN OF INTERPOLATE PENETRATION DEPTH TO TPA TIME --------
       do i = 1, TPATimeSteps
               PenDepthVsTPATime(i,1) = TPATime(i,1)
               PenDepthVsTPATime(i,2) = linearInterp(FluorideTime,
     &                 PenDepth, FluorideTimeSteps, TPATime(i,1))
       end do

c      **Begin Error Checking**
c      **These Lines Can Be Deleted**
c       print *, ' '
c       print *, 'PENETRATION DEPTHS VS TPATIME'
c       do i = 1, TPATimeSteps
c               print *, 'PenDepthVsTPATime(', i, ',2) = ',
c     &                 PenDepthVsTPATime(i,2)
c       end do
c      **End Error Checking**
c---------- END OF INTERPOLATE PENETRATION DEPTH TO TPA TIME ----------


c---------- BEGIN OF WRITE THICKNESS VS TIME --------------------------
       if (FailureFlag.eq.1) then
               print *, ' '
               print *, 'DS failure time = ', nint(FailureTime), ' years'
               FailureTimeStep = searchPosition(TPATime, FailureTime,
     &                 TPATimeSteps) + 1
       else
               print *, ' '
               print *, 'No failure of DS in ',
     &                 nint(PenDepthVsTPATime(TPATimeSteps,1)), ' years'
               FailureTimeStep = TPATimeSteps
       end if
       open (fileID1, file = fileOut1, status = 'unknown')
cccccccccc
c Janetzke --> introduce additional QA requirements (time file was created, etc)
cccccccccc
       write (fileID1,*) 'GENERATING MODULE: DSfailt'
       write (fileID1,*) 'Uniform corrosion of drip shield'
       write (fileID1,*) 'Thickness of drip shield vs time'
       write (fileID1,*) 'Number of time steps: ', FailureTimeStep
       write (fileID1,*) 'Time, yr     Thickness, m'
       do i = 1, FailureTimeStep
               write (fileID1, 9001) PenDepthVsTPATime(i,1),
```

```
     &              DSThick - PenDepth~~VsTPATime~~(i~~,2~~)
      end do
      close (fileID1)
c---------- END OF WRITE THICKNESS VS TIME FILE ----------------------
               :
               :
    subroutine DSfailtime(Fluoride~~VsTime~~, ~~TimeSteps,~~ FailureTime,
     &        PenDepth, FailureFlag)

      implicit none

      integer TimeSteps, FailureFlag, MaxTimeSteps
      double precision FailureTime, CorrRate, DSThick, Offset, slope,
     &       minF, maxF, InitialTime, InitialPenDepth, InitialCorrRate

      parameter (MaxTimeSteps = 401)

      integer i
      double precision Fluoride~~VsTime~~(MaxTimeSteps~~1000000,2~~), PenDepth(MaxTimeSteps~~1000000,1~~),
     &       FluorideCorrRate(MaxTimeSteps~~1000000,2~~), Time(MaxTimeSteps)

      external Int, DSenhance, linearInterp
      double precision DSenhance, linearInterp

      common /DS1/ CorrRate, DSThick
      common /DS2/ slope, minF, maxF
      common /DS3/ Time, TimeSteps
               :
               :

c---------- BEGIN OF CALCULATE ENHANCED CORROSION RATE ------------------
      do i = 1, TimeSteps
             ~~FluorideCorrRate(i,1) = FluorideVsTime(i,1)~~
             FluorideCorrRate(i~~,2~~) =
     &              DSenhance(Fluoride~~VsTime~~(i~~,2~~), slope, minF, maxF) *
     &              CorrRate
      end do
c---------- END OF CALCULATE ENHANCED CORROSION RATE --------------------


c---------- BEGIN OF INTEGRATE FOR PENETRATION DEPTH --------------------
      Offset = 0.5 * (FluorideCorrRate(1~~,2~~) + InitialCorrRate) *
     &       (Time~~FluorideCorrRate~~(1,1) - InitialTime) + InitialPenDepth
      call Int(FluorideCorrRate, ~~TimeSteps,~~ Offset, PenDepth)
c---------- END OF INTEGRATE FOR PENETRATION DEPTH ----------------------


c---------- BEGIN OF SET FAILURE FLAG AND CALCULATE FAILURE TIME --------
      if (DSThick.gt.PenDepth(TimeSteps~~,1~~)) then
             FailureFlag = 0
      else
             FailureFlag = 1
             if (DSThick.lt.PenDepth(1~~,1~~)) then
                     if (PenDepth(1~~,1~~).eq.InitialPenDepth) then
                            FailureTime = InitialTime
                     else
                            FailureTime = InitialTime +
     &                         (FluorideCorrRate(1~~,1~~) - InitialTime) *
     &                         (DSThick - InitialPenDepth) /
     &                         (~~FluorideCorrRate~~PenDepth(1~~,2~~) - InitialPenDepth)
                     end if
                     if (FailureTime.lt.dble(0.0)) FailureTime=dble(0.0)
             else
                     FailureTime =
     &                     linearInterp(PenDepth, FluorideCorrRate,
     &                     TimeSteps, DSThick)
             end if
      end if
c--------- END OF SET FAILURE FLAG AND CALCULATE FAILURE TIME -----------
               :
               :
    subroutine Int(Integrand, ~~Steps,~~ Offset, Integral)

      implicit none
```

```
 integer TimeSteps, MaxTimeSteps
 double precision Offset

 parameter (MaxTimeSteps = 401)

 integer i
 double precision  Integrand(MaxTimeSteps~~1000000,2~~), Integral(MaxTimeSteps~~1000000,1~~),
&       Time(MaxTimeSteps)

  common /DS3/ Time, TimeSteps
          :
          :
do i = 1, Steps
        Integral(i~~,1~~) = 0
 end do
 Integral(1~~,1~~) = Offset
 do i = 2, Steps
        Integral(i~~,1~~) = Integral(i-1~~,1~~) +
&               0.5 * (Integrand(i~~,2~~) + Integrand(i-1~~,2~~)) *
&               (Time~~Integrand~~(i~~,1~~) - Time~~Integrand~~(i-1~~,1~~))
 end do
 end
          :
          :
 function  linearInterp(x, y, dimen, xo)

 implicit none

 integer pos, dimen, MaxTimeSteps
 double precision linearInterp, xo, yo

 parameter (MaxTimeSteps = 401)

 double precision x(MaxTimeSteps~~1000000,1~~), y(MaxTimeSteps~~1000000,1~~)

 external searchPosition
 integer searchPosition
          :
          :
 function searchPosition(vector, elem, dimen)

 implicit none

 integer low, high, med, dimen, pivI, searchPosition,
&        MaxTimeSteps
 double precision elem, piv

 parameter (MaxTimeSteps = 401)

 double precision vector(MaxTimeSteps~~1000000,1~~)
```

April 11, 2002

Improve code Efficiency.

Combine all the parameter (MaxTimeSteps = 401) into an include file. Combine all common /DS3/ Time, TimeStep statements into an include file.

Edit *dsfailt.f*

```
    program DSfail

      implicit none

      integer fileID1, TimeSteps, MaxTimeSteps, FailureFlag
      double precision CorrRate, DSThick, slope, minF, maxF,
     &       FailureTime

      include 'dsfailta.i'

      integer i
      double precision Time(MaxTimeSteps), Fluoride(MaxTimeSteps), PenDepth(MaxTimeSteps)

      character fileIn*50, fileOut1*50, aline*50, InputFile*50

      common /DS1/ CorrRate, DSThick
      common /DS2/ slope, minF, maxF
      common /DS3/ Time, TimeSteps
      include 'dsfailtb.i'
               :
               :
    subroutine DSfailtime(Fluoride, FailureTime, PenDepth,
     &        FailureFlag)

      implicit none

      integer FailureFlag, TimeSteps, MaxTimeSteps
      double precision FailureTime, CorrRate, DSThick, Offset, slope,
     &       minF, maxF, InitialTime, InitialPenDepth, InitialCorrRate,
     &       DSenhance, linearInterp

      parameter (MaxTimeSteps = 401)
      include 'dsfailta.i'

      integer i
      double precision Fluoride(MaxTimeSteps), PenDepth(MaxTimeSteps),
     &       FluorideCorrRate(MaxTimeSteps), Time(MaxTimeSteps)

      common /DS1/ CorrRate, DSThick
      common /DS2/ slope, minF, maxF
      common /DS3/ Time, TimeSteps

      include 'dsfailtb.i'

      parameter (InitialTime = 0.0, InitialPenDepth = 0.0,
     &       InitialCorrRate = 0.0)
               :
               :
     subroutine Int(Integrand, Offset, Integral)

      implicit none

      integer TimeSteps, MaxTimeSteps
      double precision Offset

      parameter (MaxTimeSteps = 401)
      include 'dsfailta.i'

      integer i
      double precision Integrand(MaxTimeSteps), Integral(MaxTimeSteps)

      common /DS3/ Time, TimeSteps
      include 'dsfailtb.i'
               :
               :
      function  linearInterp(x, y, dimen, xo)
```

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C. Grossman

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```
      implicit none

      integer pos, dimen, searchPosition, MaxTimeSteps
      double precision linearInterp, xs, ys

      parameter (MaxTimeSteps = 401)
      include 'dsfailta.i'

      double precision x(MaxTimeSteps), y(MaxTimeSteps)
            :
            :
      function searchPosition(vector, elem, dimen)

      implicit none

      integer low, high, med, dimen, pivI, searchPosition, MaxTimeSteps
      double precision elem, piv

      parameter (MaxTimeSteps = 401)
      include 'dsfailta.i'

      double precision vector(MaxTimeSteps)
            :
            :
```

Created two include files, *dsfailta.i* and *dsfailtb.i*

Create dsfailta.i

```
c Include file for dsfailt.f

      integer MaxTimeSteps
      parameter (MaxTimeSteps = 401)
```

Create dsfailtb.i

```
c Include file for dsfailt.f

      integer TimeSteps
      double precision Time

      common /DS3/ Time(MaxTimeSteps), TimeSteps
```

I have reviewed this scientific notebook and find it in complimce w/ QAP-001 Requirement that there is sufficient information that the work could be repeated by a qualified individual.

JRWhite 11-08-05