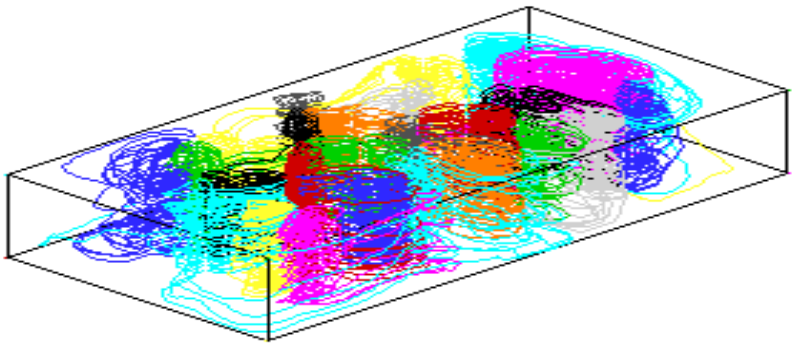
TRACE3D

Trajectory-Based Flow and Transport Simulation and Inversion

-User Manual



Texas A&M University

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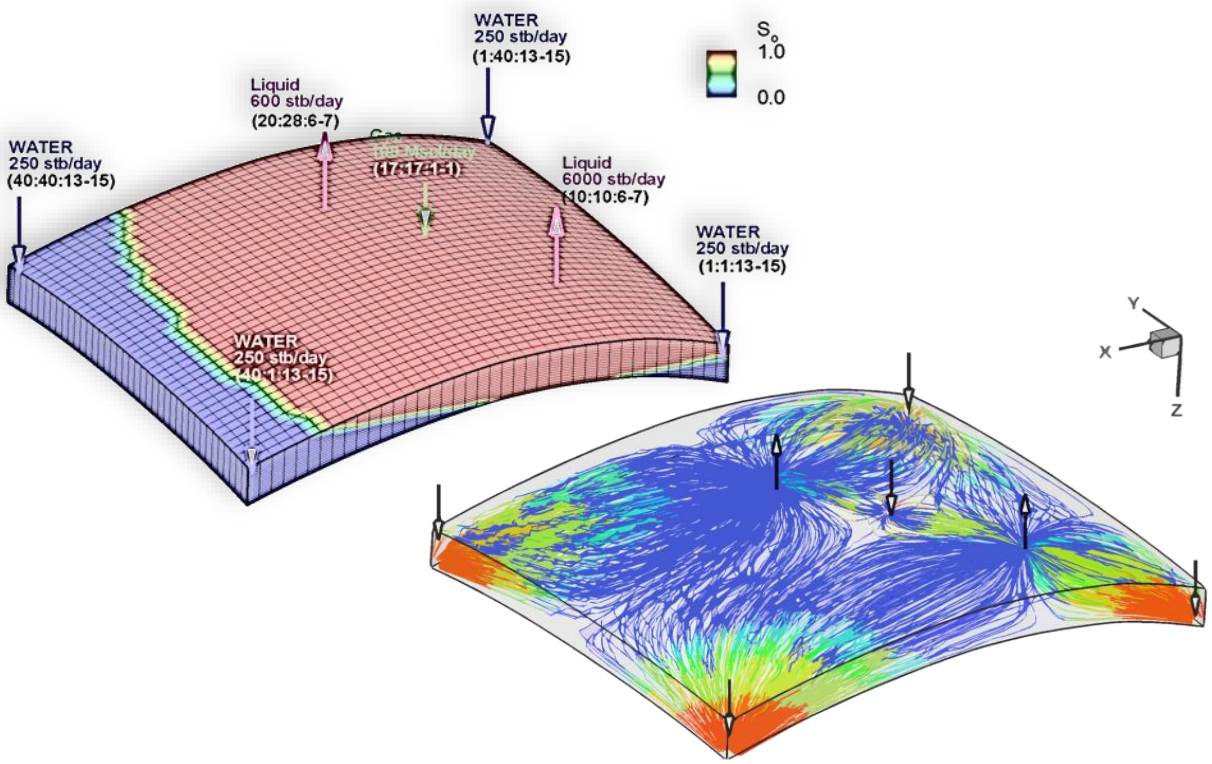
1. Introduction

This is a user manual for **TRACE3D***,* a three-dimensional streamline-based simulator with an inversion module. The source is written in FORTRAN 90 while the executable supplied with the GUI is compiled under Windows operating system. The following are the important features of this software.

1. Applicable for - 2-phase Oil-Water incompressible flow
   - 2-phase Oil-Water compressible flow
2. Pressure updating and recomputing streamline trajectories
3. Saturation calculation by Analytic/Numerical solution along streamlines
4. Infill drilling /changing well configurations
5. Parameter estimation via inverse methods

This simulator is meant for educational/research purposes only and is not intended for commercial use. No warranties are provided for the functioning of the simulator or accuracy of the results.



1.1 Installing and running TRACE3D

The steps are outlined below for installation of TRACE3D and getting started.

- Double click on the setup file (T3DSetup.exe).
- Follow the steps to install the program.
- It is recommended to install the program with a simple path name without space or special characters, for example, C:/TRACE3D.
- The installation process will generate an ‘icon’ for the program.
- Double click the icon (or use the Start menu) to start the program.
- Refer to the ‘Interface Manual’ for step by step instructions for running the program.

2. Input and Output Files

2.1 File Name Definition

File names of input data are pre-defined and cannot be changed. The input data consists of 4 files which are named as follows:

- **RESERVOIR.DATA**
- **WELL.DATA**
- **SIMULATION.DATA**
- **WELL_OBSERVED.DATA (for inverse module only)**

These input files must be created in the appropriate project folder (see the details in the interface manual). The output files are also created in the same folder where the input files are located. Brief descriptions of debug and plotting output files are given below.

File name	Contents of some files by forward simulation
S3D_dbg.out	This log file contains useful diagnostic information about the status of the run. It is a good idea to check this file after every run. It contains the contents of the DOS window that appears during execution of the program.
S3D_Run_Streamline.out	Configuration of three-dimensional streamlines. Gives the 3-D streamlines co-ordinates. Can be directly input to Tecplot360.
*.dbg	Simulation run information for debugging purposes
*.plt	Outputs in Tecplot360 format, contains initial and dynamic reservoir parameter.
*.xls	Output by Microsoft Excel format, or csv data. *_well.xls is for the sink/source, *_mbe.xls is for material balance information, and *_Grid.xls is for grid saturation or pressure

File name	Contents of some files generated by inverse modeling
S3D_Inv_RMSError.out	Mismatch between calculation and observation data. Contains water cut amplitude and travel time shift RSME through inversion iterations
S3D_Inv_InitObsCalWCT.out	Contains water cut data for each producer well. Time in column 1, observed data in column2 and initial model water cut in column 3
S3D_HM_*.plt	Output history matching data by tecplot360 format
S3D_HM_*.out	History of the objective function through iteration
PermChange_XXX.plt	Permeability change at fractional time step and cumulative, through all the iteration by tecplot format.
*.KOOO	Temporary binary output of sensitivity during history-match
*.SOOO	Production information, follows ECLIPSE binary format.
*.XOOO	Output grid dynamic properties, follows ECLIPSE binary format.

2.2 Details of Input Data

In **TRACE3D**, all input data should be entered as a combination of a "label or keyword", and then the “data values”. The keywords are self-explanatory and are similar to the ones used by commercial simulators, for example ECLIPSE™. An example of a data group is given below.

RUNSPEC	**label**
DIMENS	**keyword**
21 21 1/	**data value**

The order of input for each data group is flexible. There are a total of 8 labels that specify where to define a keyword. These are as follows.

- RUNSPEC
- GRID
- EDIT
- PROPS
- SOLUTION
- SCHEDULE
- TUNES3D

Labels must be specified in appropriate input files as given below. However not all labels are necessary

RESERVOIR.DATA: specifies the following labels
-> **RUNSPEC, GRID, EDIT, PROPS, REGIONS, SOLUTION, SUMMARY**
WELL.DATA: specifies the following labels
-> **SCHEDULE**
SIMULATION.DATA: specifies the following labels
-> **TUNES3D**
WELL_OBSERVED.DATA: specifies the observed data for inverse module
-> **For history matching only**

2.3 keywords

RUNSPEC (RESERVOIR.DATA)

- DIMENS …….. Dimensions of the reservoir grids
- INCLUDE …….. Specify Include file which has RUNSPEC data
- OIL …….. Define oil phase
- START …….. Start date
- TABDIMS …….. Maximum PVT/Rock table dimension
- WATER …….. Define water phase
- WELDIMS …….. Maximum well dimension

GRID (RESERVOIR.DATA)

- COORD …….. Specify corner point geometry
- COPY …….. Copy same dimensional data
- DX/DXV …….. Grid length for X direction
- DY/DYV …….. Grid length for Y direction
- DZ/DZV …….. Grid length for Z direction
- EQUALS …….. Specify uniform reservoir parameter
- MULTIPLY …….. Specify multiplier of reservoir parameter
- NTG …….. Net to Gross ratio
- PORO …….. Porosity
- PERMX …….. Permeability for X-direction
- PERMY …….. Permeability for Y-direction
- PERMZ …….. Permeability for Z-direction
- TOPS …….. Reservoir surface depth
- ZCORN …….. Specify corner point geometry, depth line
- INCLUDE …….. Specify Include file which has GRID section data

EDIT (RESERVOIR.DATA)

- MULTIPLY …….. Multiply parameter by factor

PROPS (RESERVOIR.DATA)

- DENSITY …….. Density of each phase
- PVDO …….. Oil PVT table
- PVTW …….. Water PVT table
- ROCK …….. Rock compressibility
- SWOF …….. Oil-Water relative permeability
- INCLUDE …….. Specify Include file which has PROPS section data

EDIT (RESERVOIR.DATA)

- MULTIPLY …….. Specify multiplier of reservoir parameter

SOLUTION (RESERVOIR.DATA)

- EQUIL …….. Initial equilibrium condition
- PRESSURE …….. Initial reservoir pressure
- SWAT …….. Initial reservoir water saturation
- SOIL …….. Initial reservoir oil saturation

SCHEDULE (WELL.DATA)

- DATES …….. Simulation and output/report dates
- TSTEP …….. General time step control
- MAXDT …….. Maximum allowable pressure and saturation step (TRACE3D only)
- WELSPEC …….. Well definition, location, completion and control (TRACE3D only)
- WELSPECS …….. Well definition, location and preferred phase
- COMPDAT …….. Well completion parameters
- WCONPROD …….. Production well control parameters
- WCONINJE …….. Injection well control parameters
- WCONHIST …….. Production well control by History (For Inversion)
- WCONINJH …….. Injection well control by History (For inversion)

TUNES3D (SIMULATION.DATA)

- FDMETHOD …….. Finite difference method
- PSOLVER ……. Linear matrix solver for IMPES pressure
- SSOLVER …….. Linear matrix solver for saturation
- NUMLINE …….. Number of streamlines
- SL1DCON …….. Streamline 1D saturation solver controller
- CFL …….. Courant- Friedrichs - Lewy (CFL) number
- CFLG …….. CFL number for gravity/grid based IMPES
- BPCONST …….. Constant pressure for block
- OPTIONS3D …….. Flags for various numerical option for simulation
- OUTPUTS3D …….. Flags for output file

Keywords for History Matching in SIMULATION.DATA

- AVGSENS ..... Average sensitivity by moving window algorithm
- DOINV ..... Run Streamline-based history matching
- OBJINV ..... Specify objective function for inversion
- OPTINV ..... Option for History-Matching
- PERMFILE ..... preprocessing permeability file before history matching
- MAXPARAM ..... Maximum value to limit reservoir property update
- MINPARAM ..... Minimum value to limit reservoir property update
- MISFCRIT ..... Minimum misfit criteria to terminate history-matching
- UPWELGRD ..... Weight to change well grid properties
- SNSTIMWT ..... Cutoff weight of the objective function
- LSQOPT ..... Options for least square algorithm includes damping/smoothing

WELL_OBSERVED.DATA (For History-Matching)

- Specifies observed data for inversion module

2.3.1 RUNSPEC section: Explanatory keywords

DIMENS

- The keyword specifies the dimensions of the reservoir grid by three integer for x,y and z direction. X-direction should be more than 1.

DIMENS	nx, ny, nz/

where:

nx: Number of gridblocks in the x direction in Cartesian coordinate

ny: Number of gridblocks in the y direction in Cartesian coordinate

nz: Number of gridblocks in the z direction in Cartesian coordinate

-- EXAMPLE, 2D Areal 20 by 20 gridblocks

```
DIMENS
20      20      1/
```

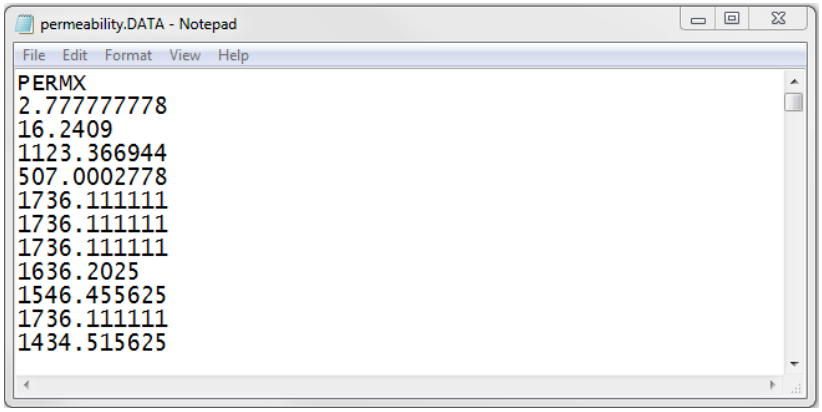
INCLUDE

- This keyword specifies the include file which contains keywords and data for RUNSPEC (or, GRID, PROPS etc.) Include file

INCLUDE	File name /

-- EXAMPLE
INCLUDE
permeability.DATA /

(specified file)



OIL / WATER

- The keyword specifies fluid phases in the reservoir. Absence of phase keyword might cause skipping of other keywords related to that specific phase.

OIL	-
WATER	-

-- EXAMPLE: 2phase oil and water case –

OIL

WATER

START

- The keyword specifies the starting date of the simulation. TRACE3D will use these information only if inversion module is used (Used in output file for *.S000, *.X000 etc.)

START	Sim_time_start_day, mon, year /

where:

Sim_time_start_day: date, default = 1

Sim_time_start_mon: month, default = JAN

Sim_time_start_yar: year, default = 2000

-- EXAMPLE

START

1 JAN 2000 /

Note that months are abbreviated with the first three letter, for example JAN, FEB, MAR, etc.

TABDIMS

- This keyword specifies the maximum number of rock table (SWOF, SGOF) or PVT table (PVDO) dimensions. Note that SATNUM, PVTNUM is required to specify Rel-perm and PVT region specified here.

TABDIMS	Max_RockTable_Num, Max_PVTTable_Num, Max_RockTable_Row, Max_PVTTable_Row /

where:

Max_RockTable_Num:	Maximum number of rock table, default = 1
Max_PVTTable_Num:	Maximum number of PVT table, default = 1
Max_RockTable_Row:	Maximum row of rock table, default = 1000
Max_PVTTable_Row:	Maximum row of PVT table, default = 200

```
-- EXAMPLE
-- the field with 2 rock type (2 SWOF table assigned in input)
TABDIMS
2 1 1* 1*  /
```

WELLDIMS

- The keyword specifies the maximum well number of wells and completions.

WELLDIMS	Max_Well, Max_Conn_Per _Well /

where:

Max_Well:	Maximum number of wells; default = 50
Max_Conn_Per _Well:	Maximum number of completion per well, default = 50

-- EXAMPLE

-- A field with 500 wells with more than a thousand of completion points per well

```
WELLDIMS
500 1500   /
```

2.3.2 GRID section keywords

COORD

- Specify grid geometry by corner point format as used in the reservoir simulator ECLIPSE™. The number of data point required is (nx+1)*(ny+1)*(nz+1) to describe the corner point geometry. The ZCORN is required to fully specify the grid.

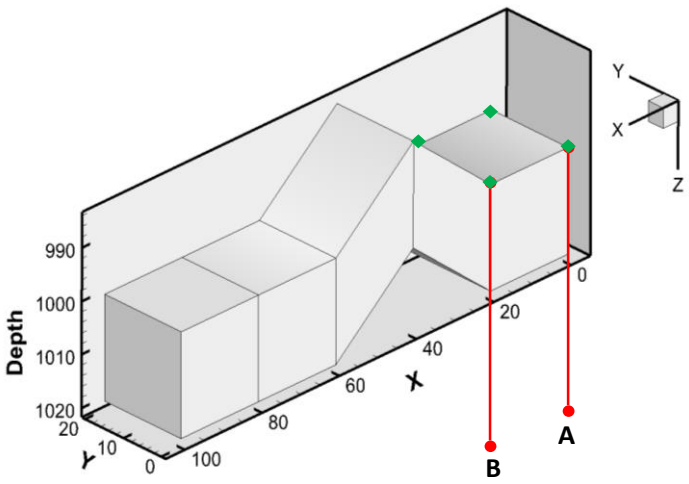
The COORD gives the top and bottom location of the coordinate lines, four of which define a pillar of grid blocks. The first three column in the COORD data represent the top (x,y,z) position of the coordinate line while the last 3 columns the bottom position.

Once the pillars have been defined throughout the domain using coordinate lines, positions of grid block corners (8 per grid block) are identified using ZCORN.

COORD	Grid coordinate (nx+1*ny+1*nz+1)

-- Example 1D 5grid CPG model

```
COORD
0     0     1000   0     0     1100   →A
20    0     1000   20    0     1100   →B
40    0     1000   40    0     1100
60    0     1000   60    0     1100
80    0     1000   80    0     1100
100   0     1000   100   0     1100
 0    20    1000   0     20    1100
20    20    1000   20    20    1100
40    20    1000   40    20    1100
60    20    1000   60    20    1100
80    20    1000   80    20    1100
100   20    1000   100   20    1100
/
ZCORN
4*1000 2*985  8*1000 2*985  4*1000
4*1020 2*1005 8*1020 2*1005 4*1020
/
```



COPY

- This keyword allows copying of datasets with similar dimensions. Used **only to copy permeability** (e.g. PERMX to PERMZ). Other parameters are not allowed in TRACE3D.

COPY	Target , Reference /

-- EXAMPLE, copy permx to permz –
COPY
PERMY PERMX/
PERMZ PERMX/
/

DX /DY /DZ

- This keyword specifies the length of each grid block. The grid size can be variable in each direction. See the example below.

DX	dx(nxyz)
DY	dy(nxyz)
DZ	dz(nxyz)

-- EXAMPLE (3*3*2) RESERVOIR
DX
6*10 6*30 6*60 /
DY
18*100/
DZ
9*50 9*25/

DXV/DYV /DZV

- This keyword specifies the length of grid in each direction. The grid size can be variable in each direction. See example below.

DXV	dx(nx)
DYV	dy(ny)
DZV	dz(nz)

-- EXAMPLE (3*3*2) RESERVOIR
DXV
10 30 60 /
DYV
3*100/
DZV
50 25/

EQUALS

- This keyword allows user to input uniform grid properties efficiently. Supported keywords of the reservoir properties are: DX,DY,DZ,PERMX,PERMY,PERMZ,PORO,TOPS/

EQUALS	Param_Name, Value /

where:
Param_Name: Name of the parameter (PERM or PORO, PORV)
Value: Value to apply properties

```
-- EXAMPLE–
EQUALS
DX   10.0 /
DY   10.0 /
DZ   10.0 /
PERMX   100.0 /
PERMY   100.0 /
PREMZ   1.0 /
PORO   0.25 /
TOPS    2500.0 /
/
```

MULTIPLY

- This keyword allows a multiplying factor for grid properties. Supported keywords are: PERMX,PERMY,PERMZ,PORV,PORO. **The transmissibility multiplier is not allowed here (only available at EDIT section).**

MULTIPLY	Param_Name, LocXi, LocXe, LocYi, LocYe, LocZi, LocZe, MFactor

where:

Param_Name: Name of the parameter to multiply factor, (PERM or PORO, PORV)

LocXi: Start X-grid for multiplier

LocXe: End X-grid for multiplier

LocYi: Start Y-grid for multiplier

LocYe: End Y-grid for multiplier

LocZi: Start Z-grid for multiplier

LocZe: End Z-grid for multiplier

Mfactor: Multiplier for the property

```
-- EXAMPLE–
MULTIPLY
PORO 1 10 1 10 5 5  1.25 /
PREMZ 1 10 1 10 1 10 0.1 /
/
```

NTG

- This keyword specifies the Net to Gross ratio of the reservoir. Note that NTG affects both porosity and transmissibility throughout the simulation, except for vertical transmissibility. Default = 1.0 and value must be between 0.0 to 1.0.

NTG	Reservoir net gross ratio (nx*ny*nz)

- EXAMPLE (3*3*2) RESERVOIR, low sand quality at bottom layer –

NTG
9*0.85/
9*0.25/

PERMX/ PERMY/ PERMZ

- This keyword specifies the x,y and z direction permeability of the reservoir.

PERMX	kx(nx,ny,nz)
PERMY	ky(nx,ny,nz)
PERMZ	kz(nx,ny,nz)

- EXAMPLE (3*3*2) RESERVOIR –

PERMX
18*100.0/
PERMY
18*100.0/
PERMZ
18*5.0/

PORO

- This keyword specifies the porosity of the reservoir.

PORO	Reservoir porosity (nx*ny*nz)

- EXAMPLE (3*3*2) RESERVOIR –

PORO

18*0.25/

TOPS

- This keyword specifies the top surface depth of the reservoir.

TOPS	Reservoir surface depth (nx*ny)

- EXAMPLE–

TOPS

900 900 900 900 875 850 850 850 840 830 825 825 800 800 800 800 825 825 850 850 875 875 880 885 887 890 900 900 900 900 900 900 875 875 860 850 850
900 900 875 860 850 840 825 810 800 780 770 760 755 750 750 760 785 790 800 815 825 830 850 860 870 875 875 875 880 890 890 890 860 860 850 845 830
950 925 900 880 870 860 850 825 800 780 770 770 770 780 780 780 790 800 810 800 820 840 850 855 875 900 900 910 910 910 910 905 900 888 875 860 850
950 925 910 880 850 830 899 780 770 760 760 760 755 755 766 770 770 770 775 780 785 790 800 810 815 850 855 855 855 860 865 875 850 850 810 800 800
900 880 880 850 825 790 770 760 755 750 740 735 725 730 735 740 745 750 750 760 770 775 780 790 800 800 800 820 820 820 820 815 810 800 800 775 760
900 875 850 850 850 775 760 750 745 725 720 710 710 710 710 715 700 725 730 740 745 745 750 753 780 775 780 785 790 790 790 790 780 775 770 760 755
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900 860 840 800 770 760 750 740 720 700 680 680 670 660 650 645 630 620 600 590 580 580 575 565 560 560 560 560 560 560 565 570 570 570 575 575 580
900 880 850 825 800 780 760 750 740 720 700 690 670 660 655 650 640 625 610 600 590 580 580 580 575 575 575 580 580 585 585 590 590 600 605 610 620
925 900 870 840 815 800 775 760 750 740 720 700 695 675 660 655 650 645 630 620 615 610 600 600 600 600 600 600 600 600 600 605 605 605 610 610 615
940 920 880 860 840 810 790 770 760 750 740 720 710 700 680 670 665 660 650 650 640 640 640 640 630 620 620 625 630 635 630 630 625 635 635 635 640
960 940 910 900 860 840 815 800 780 760 750 740 725 715 700 690 680 675 670 660 660 650 650 650 640 640 640 640 640 635 635 630 630 635 635 640 645
960 950 925 900 875 860 840 820 800 780 760 750 740 730 720 700 690 680 675 675 670 660 650 660 660 660 665 665 665 670 675 680 685 685 690 700 705
970 960 950 920 900 860 840 820 800 790 770 760 750 740 730 720 710 700 690 680 675 675 675 680 680 690 690 690 695 695 700 700 700 710 720 725 730
990 970 960 950 945 925 900 875 850 825 800 780 760 755 750 740 735 725 725 715 710 705 700 700 700 700 700 710 715 720 725 730 735 735 740 740 750
990 990 970 960 955 950 940 910 900 880 850 850 825 800 780 770 760 755 750 750 740 740 735 735 735 730 735 740 740 740 740 745 745 745 750 760 770
990 990 990 990 990 990 950 940 925 900 875 860 840 825 800 790 780 775 775 760 760 755 755 755 755 760 760 760 760 760 760 765 770 775 780 785 790
990 990 990 990 990 990 990 950 945 935 925 900 880 865 850 840 820 800 790 780 775 775 775 775 780 780 780 785 785 785 785 785 785 785 785 789 790
990 990 990 990 990 990 990 990 990 990 950 940 930 920 910 900 875 850 840 830 825 820 810 810 810 810 810 810 810 810 810 810 820 820 830 830 840 850
990 990 990 990 990 990 990 990 990 990 970 950 940 930 925 920 910 900 890 870 860 850 850 840 835 835 835 840 840 840 845 845 850 855 860 875 890 900

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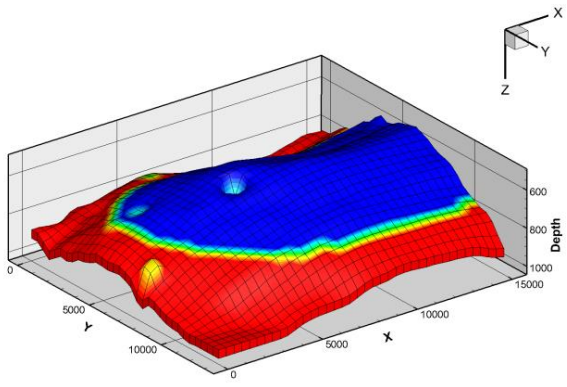


ZCORN

- Specify grid geometry by corner point format used in ECLISPE™ commercial reservoir simulator. The data point is 8 corners per grid and thus total 8*nx*ny*nz values must be specified to describe depths of corner point geometry. The COORD is required to fully specify the grid.

The ZCORN specify multiple points along predefined coordinate lines. Connecting these points together creates top and bottom surface for grid blocks. Note that sequence of the data should follow similar order as the COORD lines definition.

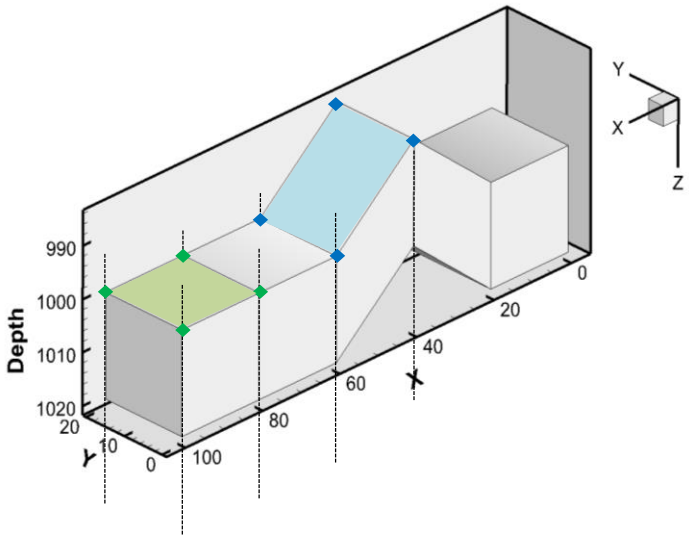
ZCORN	Gird coordinate depth (2nx*2ny*2nz)

-- Example 1D 5grid CPG model

COORD

0	0	1000	0	0	1100
20	0	1000	20	0	1100
40	0	1000	40	0	1100
60	0	1000	60	0	1100
80	0	1000	80	0	1100
100	0	1000	100	0	1100
0	20	1000	0	20	1100
20	20	1000	20	20	1100
40	20	1000	40	20	1100
60	20	1000	60	20	1100
80	20	1000	80	20	1100
100	20	1000	100	20	1100

/



ZCORN

4*1000 2*985 2*1000 4*1000 2*1000 2*985 4*1000

4*1020 2*1005 2*1020 4*1020 2*1020 2*1005 4*1020

/

2.3.3 PROPS section keywords

DENSITY

- This keyword specifies the fluid density at surface conditions.

DENSITY	deno, denw

where:

deno: Oil density, lb/cft (default : 37.457 [lb/cft])

denw: Water demsoty, lb/cft (default : 62.336 [lb/cft])

-- EXAMPLE–

DENSITY

45 63 1*/

PVDO

- This keyword specifies PVT table for oil. Space or comment lines are not allowed between table columns.

PVDO	Po, Bo, μo /

where:

P_o: Table for pressure for oil [psi]

B_o: Table for oil formation volume factor [rb/stb]

μ_o: Table for oil viscosity [Cp]

-- EXAMPLE–

```
PVTO
800     1.125   0.92
2200    1.121   0.985
5600    1.116   1.125 /
```

PVTW

- This keyword specifies PVT table for water. The table is limited to 1-row shown as example.

PVTW	Pwref, Bw, cw, μw, μcwg

where:

P_{wref}: The reference water phase pressure [psi]

B_w: The water formation volume factor [rb/stb]

c_w: The water compressibility [psi^{-1}]

μ_w: The water viscosity [Cp]

μ_{cwg}: The water viscosibility

-- EXAMPLE–

PVTW

3600.0 1.0341 3.0E-06 0.52341 1.0E-05 /

ROCK

- This keyword specifies the rock compressibility.

ROCK	Pref, cr

where:

P_{ref}: Reference pressure [psi]

c_r: Rock compressibility, [psi^{-1}]

-- EXAMPLE–

ROCK

3600 3.6d-5 /

SWOF

This keyword specifies water-oil saturation table. You can specify only one SWOF keyword throughout the simulation. The number of rows in the table is arbitrary. If you do not specify this keyword, the program will use straight line functions with no residual term. If 3-phase, Stone-2 equation will be used for oil relative permeability. Space or comment lines are not allowed between table columns.

SWOF	Sw, krw, krow, Pcow

where:

S_w: Water saturation ($S_{wc} < S_w < 1.0-S_{or}-S_{gr}$)

k_{rw}: Relative permeability of water

k_{row}: Relative permeability of oil

P_{cow}: Oil-water capillary pressure [psi]

```
-- EXAMPLE–
SWOF
--  Sw     Krw     Krow     Pcow
0.00000 0.00000 1.00000 0.00000
0.10000 0.01000 0.81000 0.00000
0.20000 0.04000 0.64000 0.00000
0.30000 0.09000 0.49000 0.00000
0.40000 0.16000 0.36000 0.00000
0.50000 0.25000 0.25000 0.00000
0.60000 0.36000 0.16000 0.00000
0.70000 0.49000 0.09000 0.00000
0.80000 0.64000 0.04000 0.00000
0.90000 0.81000 0.01000 0.00000
1.00000 1.00000 0.00000 0.00000
/
```

2.3.4 EDIT section keywords

MULTIPLY

This keyword allows multiplying factor for grid properties. Supported keywords are: PERMX,PERMY,PERMZ,PORV,PORO,TRNS,TRNY,TRNX. **The transmissibility multiplier can be used only with EDIT section**.

MULTIPLY	Param_Name, LocXi, LocXe, LocYi, LocYe, LocZi, LocZe, MFactor

where:

Param_Name: Name of the parameter to multiply factor, (PERM or PORO, PORV)

LocXi: Start X-grid for multiplier

LocXe: End X-grid for multiplier

LocYi: Start Y-grid for multiplier

LocYe: End Y-grid for multiplier

LocZi: Start Z-grid for multiplier

LocZe: End Z-grid for multiplier

Mfactor: Multiplier for the

```
-- EXAMPLE–
MULTIPLY
PORO 1 10 1 10 5 5  1.25 /
PREMZ 1 10 1 10 1 10 0.1 /
/
```

2.3.6 SOLUTION section keywords

EQUIL

This keyword specifies initial reservoir pressure and saturation by hydrostatic equilibrium calculation. The reference pressure refers to the dominant phase which stays at the reference depth. Do not use PRESSURE, SOIL, SWAT, RS keyword with EQUIL simultaneously. These keywords will ignore hydrostatic equilibrium conditions.

EQUIL	Depth, pref, OWC

where:

Depth:	Reference depth for pressure	[ft]
p_{ref}:	Reference pressure for depth	[psi]
OWC:	Oil-water contact	[ft]

-- EXAMPLE–

```
EQUIL
-- Reference  Reference   OWC   Pcow   GOC    Pcog
--   Depth       pressure
     2870       2814.15    2900   0.0   2765    0.0   /
```

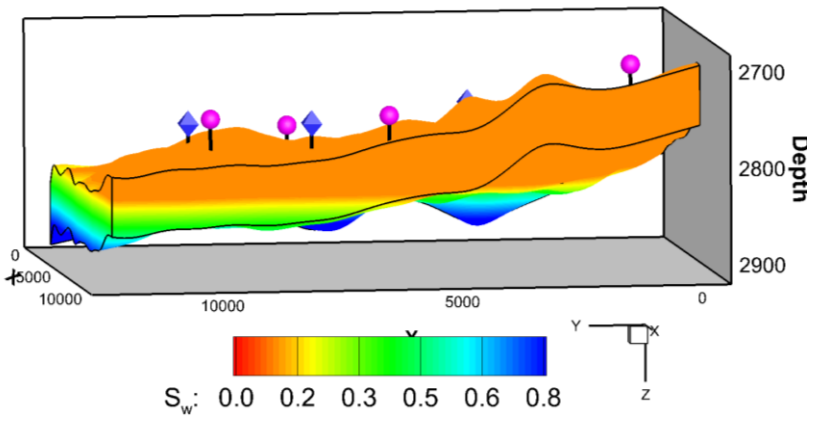


Figure. Example of water saturation by EQUIL keyword

PRESSURE/ SWAT/ SOIL/

This keywords specify initial reservoir pressure, saturation, for non-equilibrium conditions. Do not use these keyword with EQUIL simultaneously. These keywords will ignore hydrostatic equilibrium condition. You need to specify all of this keyword, once you use one of them in the SOLUTION section.

PRESSURE	p_{oil} (nx,ny,nz)
SOIL	S_o(nx,ny,nz)
SWAT	S_w(nx,ny,nz)

where:

p_{oil}:	Oil phase pressure	[psi]
S_o:	Oil saturaiton	[-]
S_w:	Water Saturation	[-]

-- EXAMPLE–

```
PRESSURE
20*3000/

SWAT
20*0.0
/
```

2.3.7 SCHEDULE section keywords

DATES

This keyword specifies the report date of the simulation and change in well condition.

DATES	Report_day, mon, year /

where:

day: date, default = given by START or previous record

mon: month, default = given by START or previous record

yar: year, default = given by START or previous record

-- EXAMPLE–

```
WCONPROD
-- name/ cond/ control/  ORAT/  WRAT/ GRAT/ LRAT/ RESV/    BHP/
PRD     OPEN      BHP          5*                  3500.0 /
/

DATES
1 JAN 2000/
/

WCONPROD
-- name/ cond/ control/  ORAT/  WRAT/ GRAT/ LRAT/ RESV/    BHP/
PRD     OPEN      BHP          5*                  3000.0 /
/

DATES
1 JAN 2001/
/
```

TSTEP

This keyword specifies the time step for simulation.

TSTEP	Times*Days/

- EXAMPLE–

```
TSTEP
10*10
/

TSTEP
1 2 7 10 10 10 10
/
```

MAXDT

This keyword specifies the maximum allowable time step size for both pressure and saturation update through the simulation. This maximum time step overrides (if applied) TSTEP or saturation time step during 1D convection calculation along Streamline.

MAXDT	Days/

- EXAMPLE–

```
-- run 100days, report 1 time, 100 pressure recalculation

MAXDT
1.0
/

TSTEP
100.0
/
```

WELSPEC

This keyword specifies all of the well data. The well can be specified for vertical well only and need to specify top and bottom of the connection. The bottom hole pressure is set for the top layer of the reservoir connected completion. Space or comment lines are not allowed between table columns.

WELSPEC	w_{cond}, x, y, z_t, z_b, w_{diam}, w_{skin}, w_{ctrl}, w_{value}, w_{target}

where:

w_{cond}:	Specify Injector/producer	[INJ--- / PRD---]
	* Identify PRDXXX = producer, INJXXX = Injector,	
x:	X-location	
y:	Y-location	
z_t:	Z-top location	
z_b	Z-bottom location	
w_{diam}:	Well diameter	[ft]
w_{skin}:	Skin factor	[psi]
w_{ctrl}:	Well control, pressure/rate	[RATE or BHP]
w_{value}:	Control value for BHP or RATE	[psi/STB]
w_{target}:	Target phase for rate specified well	[WAT (injector)] [ORAT /LRAT(producer)]

-- EXAMPLE–

```
WELSPEC
-- INJ/PRD  coord X*Y/  Z-Z/ Diameter/ Skin/ Condition/   Value/   Target/
    INJ1    5    5       1 5    0.25  0.d0      BHP   3010     WAT/
    INJ2    41   5       1 5    0.25  0.d0      BHP   3010     WAT/
    INJ3    77   5       1 5    0.25  0.d0      BHP   3010     WAT/
    INJ4    23   21      1 5    0.25  0.d0      BHP   3010     WAT/
    PRD1    5    21      1 5    0.25  0.d0     RATE   100     LRAT/
    PRD2    41   21      1 5    0.25  0.d0     RATE   100     LRAT/
    PRD3    77   21      1 5    0.25  0.d0     RATE   100     LRAT/
    PRD4    23   37      1 5    0.25  0.d0     RATE   100     LRAT/
    PRD5    59   37      1 5    0.25  0.d0     RATE   100     LRAT/
/
```

WELSPECS

This keyword specifies all of the well data using ECLIPSE input format. Here, wells, their (i,j) grid locations and preferred phase are defined. Please refer ECLIPSE™ manual for more detailed information.

WELSPECS	w_{name}, Dummy, xloc, yloc/

where:

w_{name}:	name of the well
Dummy:	not supported by TRACE3D
xloc:	X-location
yloc:	Y-location

```
-- EXAMPLE–
WELSPECS
-- name/  group/  location x*y/  deapth for bottomhole pressure/  prefer phase/
--                          (perforation position)
 TCIN_01   G1       1   1                    1*          WAT/
 TCPR_08   G1       100   1                    1*          LIQ/
/
```

COMPDAT

This keyword specifies all of the well completion data using ECLIPSE™ input format. Please refer ECLIPSE™ manual for the detail information.

WELSPEC	w_{name}, xloc, yloc, z_i, z_e, Dummy, w_{trns}, w_{diam}, Dummy, w_{skin}, 3*, w_{dir}

where:

w_{name}:	name of the well
xloc:	X-location
yloc:	Y-location
z_i:	Z-current location
z_e	Z-next location
Dummy:	not supported by TRACE3D
w_{trns}:	Well transmissibility
w_{diam}:	Well diameter [ft]
Dummy:	not supported by TRACE3D
w_{skin}:	Skin factor
Dummy:	not supported by TRACE3D
Dummy:	not supported by TRACE3D
w_{dir}:	perforation direction of the well

```
-- EXAMPLE–
COMPDAT
-- Well completion data
-- name/  coord X*Y/  Z-Z/  cond/  Non/  Trans/ Diameter/  Kh/  Skin factor/
INJ     1    1   1 1   OPEN   0     1*      0.25/
PRD     100   1   1 1   OPEN   0     1*      0.25/
/
```

WCONINJE

- This keyword specifies the injection control type following keyword in commercial simulator ECLIPSE™.

WCONINJE	w_{name}, ftype, Dummy, ControlType

where:

w_{name}:	name of the well
ftype:	injection fluid type [Oil,Water] , Default = Water
Dummy:	Not used in TRACE3D
Control Type:	RATE : surface rate (stb/day)
	RESV : reservoir volume rate (rb/day)
	BHP : bottom hole pressure (psi)

*Note: The 'ControlType' specifies primary constraint of the well. It is possible to specify secondary constraint as well, such as BHP, shown in example below. Once injector meets secondary constraint, then the well is operated by secondary constraint.

*Note: If shut of the well is required, use injection rate of 0.0 by RATE or RESV

-- EXAMPLE–

```
WCONINJE
-- name/ fluid/ cond/ control/ RATE/ RESV/ BHP/
INJ    WAT   OPEN   RESV   1*   1.0   1.E5 /
/
```

WCONPROD

- This keyword specifies the production control type following keyword in commercial simulator ECLIPSE™.

WCONPROD	w_{name}, Dummy, ControlType

where:

w_{name}:	name of the well
Dummy:	Not used in TRACE3D
Control Type:	ORAT : oil production rate (stb/day)
	WRAT : water production rate (stb/day)
	LRAT : oil+water production rate (stb/day)
	BHP : bottom hole pressure (psi)

*Note: The 'ControlType' specifies primary constraint of the well. It is possible to specify secondary constraint as well, such as BHP, shown in example below. Once injector meets secondary constraint, then the well is operated by secondary constraint.

*Note: If shut of the well is required, use injection rate of 0.0 by RATE or RESV

-- EXAMPLE–

```
WCONPROD
-- name/ cond/ control/  ORAT/  WRAT/ GRAT/ LRAT/ RESV/    BHP/
PRD     OPEN      RESV          4*                          100.0     3500.0 /
/
```

WCONHIST

This keyword specifies the production data measured through the field history. The format has similarities with WCONPROD, except ***TRACE3D constrains field withdrawal, well production (measured at surface conditions) and bottomhole pressures with the arguments (history data) supplied with this keyword***.

```
----------------------------------------
-- Time =    10.00000
----------------------------------------

WCONINJH
I1    WATER  OPEN    0.50000000E+03  1351.53027344 /
/
WCONHIST
P1    OPEN   BHP     0.50000137E+03 0.38257446E-13 0.00000000E+00  3*  0.10000000E+04
/
/
TSTEP
   10.00000000
/


----------------------------------------
-- Time =    20.00000
----------------------------------------

WCONINJH
I1    WATER  OPEN    0.50000000E+03  1351.52954102 /
/
WCONHIST
P1    OPEN   BHP     0.50000134E+03 0.95761777E-06 0.00000000E+00  3*  0.10000000E+04
/
/
TSTEP
   10.00000000
/
```

WCONINJH

This keyword specifies the injection data measured through the field history. The format has similarities with WCONINJE, except ***TRACE3D constrains well injection volumes (measured at surface conditions) and bottomhole pressures with the arguments (history data) supplied with this keyword***.

```
----------------------------------------
--  Time =     10.00000
----------------------------------------

WCONINJH
I1     WATER   OPEN     0.50000000E+03   1351.53027344 /
/
WCONHIST
P1     OPEN    BHP      0.50000137E+03  0.38257446E-13  0.00000000E+00   3*   0.10000000E+04
/
/
TSTEP
   10.00000000
/


----------------------------------------
--  Time =     20.00000
----------------------------------------

WCONINJH
I1     WATER   OPEN     0.50000000E+03   1351.52954102 /
/
WCONHIST
P1     OPEN    BHP      0.50000134E+03  0.95761777E-06  0.00000000E+00   3*   0.10000000E+04
/
/
TSTEP
   10.00000000
/
```

2.3.8 TUNES3D section keywords

CFL/CFLG

- This keyword specifies the CFL(Courant-Friedrichs-Lewy) number and minimum time-step length of 1D saturation solver on streamline.

CFL(G)	CFLnum, Minstep

where:

CFLnum	CFL number for explicit saturation calculation
MinStep:	Minimum time step for explicit time step selection

-- EXAMPLE –

CFL
-- CFL condition, for explicit
-- Minimum CFL time
1.0 1.d-3 /

CFLG
-- CFL condition for gravity
1.0 1.d-3 /

CONVERGE

- This keyword specifies convergence criteria for Newton-iteration for pressure or saturation calculations

CONVERGE	EPSP, EPSS, MAXITP,MAXITS

where:

EPSP:	Convergence criteria for pressure (Default : 1.d-2)
EPSS:	Convergence criteria for saturation (FIM, IMPLICIT on SL)
MAXITP:	Maximum iteration for pressure (Default : 30)
MAXITS:	Maximum iteration for saturation (Default : 30)

-- EXAMPLE –

CONVERGE
1.d-2 1.d-3 20 20 /

DOINV

- This keyword **activates history-matching module** with the given input of initial permeability and observation data (if WCONHIST or WCONINJEH is used, you do not need to assign observation data as additional file). General option of history matching is assigned as follows.

DOINV	MatchMethod, UseGNTN, Max_HM_Ite

where:

MatchMethod:	Amplitude matching or Generalized Travel Time match. [AMP or TTM, Default = TTM] * Amplitude matching is under development and not preferred
UseGNTN:	Gauss-Newton or least square minimization. [GNN or LSQ, Default = LSQ] * Gauss-Newton method is under development and not preferred
Max_HM_Ite:	Maximum iteration for history-matching [Default = 30]

-- EXAMPLE –

```
DOINV
TTM   LSQ   5 /
```

FDMETHOD

- TRACE3D allows finite-difference IMPES or FIM method. If this keyword is included, then we can specify finite difference IMPES or fully implicit simulation instead of streamline simulation. The default is STREAMLINE.

FDMETHOD	Finite difference method (STREAMLINE, FIM, IMPES), default = STREAMLINE

STREAMLINE/
Use Implicit solution for pressure on the grid, and explicit saturation calculations on the streamline.

IMPES/
Solve Implicit Pressure Explicit Saturation on Grid.

FIM/
Solve Implicit Pressure Implicit Saturation simultaneously on Cartesian grid.

-- EXAMPLE –
FDMETHOD
STREAMLINE/

NUMLINE

- This keyword specifies number of streamlines, starting point, treatment of missed-block.

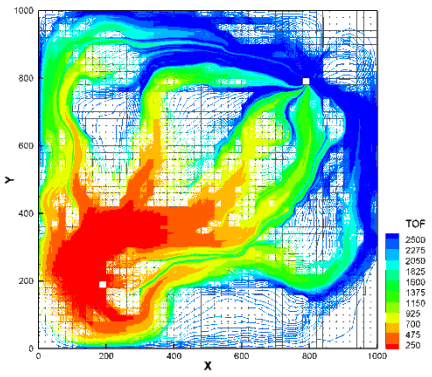
NUMLINE	NumLine, Start position, Missed-Block Option

where:

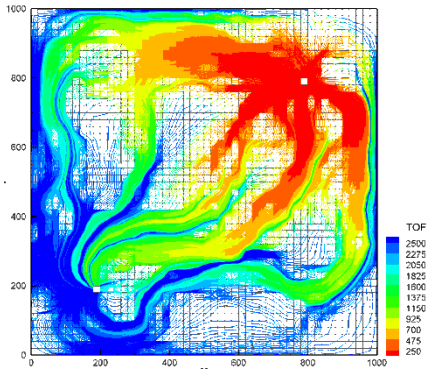
NumLine	:	Number of streamlines	
Startposition	:	Start position	[INJ/ PRD / CEL]
Missed-Block Option:		Additional SL-option	[Yes/ No]

-- EXAMPLE –

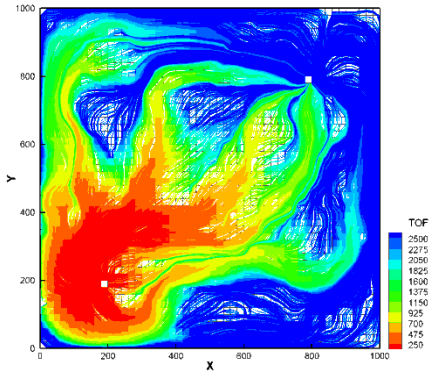
NUMLINE
500 INJ Yes /



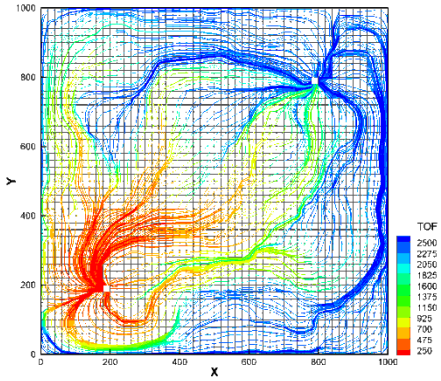
Injector start



Producer start



Cell center start



Missed-block start

OBJINV

- This keyword assigns weight for history-matching of bottom-hole pressure and water-cut. TRACE3D can match both pressure and water-cut if observation data is available. In that case, user can assign weight for matching process.

OBJINV	WCT_ Factor, BHP_Factor

where:

WCT_ Factor:	[0 >] Match WCT	(Default = 1.0, 0.0 = inactive)
BHP_Factor:	[0 >] Match BHP	(Default = 0.0, 1.0 = active)

-- EXAMPLE –
-- Water cut matching by generalized travel time method
OBJINV
1.0 0.0
/

-- EXAMPLE –
-- Multiply 10.0 to bottom hole pressure sensitivity.
OBJINV
1.0 10.0
/

OPTIONS3D

- This keyword specifies the simulation option for TRACE3D.

OPTIONS3D	Op1, Op2, Op3, Op4

where:

Op1: Pressure update interval: 0 or negative will give only 1st update.

Op2: Output to represent Fault structure (Discontinuity between grid for corner point output) by Tecplot 8-point Corner, the file size of the output will be larger.

Op3: Check irreducible saturation and constraint if saturation goes below irreducible point during simulation

Op4: Output Sensitivity by tecplot during inversion run

-- EXAMPLE –

```
OPTIONS3D
-- Every Pressure Update
1 2 1 1 /

OPTIONS3D
-- First step update only
0 0 0 0 /
```

OPTINV/ MAXPARAM/ MINPARAM/ MISFCRIT/ AVGSENS/ UPWELGRD/ LSQOPT / SNSTIMWT

- These keyword assigns optional values and constraint during data-matching process.

OPTINV : 5 parameter to give constraints on permeability change per iteration step
-- [0 >] Lim of Param Update, Global scale (1 = less than 100% per step), Def = 0
-- [0 >] Lim of Param Update, Grid scale (1 = less than 100% per step), Def = 0
-- [0 >] Give Constraint Before LSQR, by predicting dlnk in average sens, WCT, Def = 2
-- [0 >] Give Constraint Before LSQR, by predicting dlnk in average sens, BHP, Def = 2
-- [0 >] Multiplication to the increment of the permeability update (dk), Def = 1.0

MAXPARAM: 1 parameter to give maximum possible value of permeability
-- Maximum updated Parameter [Def = Maximum Prior]

MINPARAM: 1 parameter to give minimum possible value of permeability
-- Maximum updated Parameter [Def = Minimum Prior]

MISFCRIT: 2 parameter to give minimum misfit limit to stop history-matching iteration
-- WCT(TTime) Misfit Criteria(Dont inv below this number) [Def = 10.0]
-- BHP Misfit Criteria(Dont inv below this number) [Def = 10.0]

AVGSENS: 2 parameter to give window average of WCT/BHP sensitivity
-- Moving average sensitivity WCT [Def = 2]
-- Moving average sensitivity BHP [Def = 5]

SNSTIMWT: Cutoff-factor of the sensitivity for with respect to time. For instance, 0.9 means 10% of sensitivity is ignored with smaller misfit function at during operation
-- Cutoff sensitivity for WCT [Def = 1.0]
-- Cutoff sensitivity for BHP [Def = 1.0]

UPWELGRD: 1 parameter to give change in well grid permeability to match WCT/BHP
-- [Def = 1.0], below zero will not update

LSQOPT: 2 parameter to give constraint for Least Square Alrithm.
-- MxIte NormConst SmthCstH SmthCstV
-- [Def = 400,0,0,0]

OUTPUTS3D

- This keyword specifies which file format to output solution data. By default, TRACE3D will provide necessary information for visualization. Use wisely if you need additional information since it increases simulation time and output file space.

OUTPUTS3D	Op1, Op2, Op3, Op3, Op5, Op6,Op7, Op8,Op9

where:

Op1: Debug file, for diagnosis.
Op2: Output Block information by Excel
Op3: Output Block information by Tecplot format
Op4: Output Streamlines by Tecplot format
Op5 Output Streamlines with Diffusive TOF by Tecplot format
Op6: Output Pressure Jacobian matrix
Op7: Output Saturation Jacobian matrix
Op8: Output TRACE3D information for visualization
Op9: Output TRACE3D inversion information

-- EXAMPLE –

```
OUTPUTS3D
-- Output Debug           [Text    , dbg.out]
-- Output Dynamic Data      [Excel   , Grid_*.xls]
-- Output Dynamic Data      [TecPlot ,     *.plt]
-- Output Streamline        [TecPlot , Strea*.plt]
-- Output Diffusive TOF     [TecPlot , Strea*.plt]
-- Output Pressure Matrix    [Excel   , PMtrx .xls]
-- Output Saturation Matrix  [Excel   , SMtrx .xls]
-- Output TRACE3D Interface View [Text    , S3D_* .out]
-- Output by ECLIPSE  format [Binary ,     *.X000]
-- Output by FrontSim format [Binary ,     *.SLN ]
1 0 0 0 0 0 0 1 /
```

PERMFILE

This keyword perform pre-processing of File-I/O operations before history matching.
The keyword is useful to perform history matching multiple times because user can avoid manual copy/paste process to regenerate original permeability.
The `PERM_IncludeFile_Initial` should be include file specified at GRID section and `PERM_IncludeFile_Update` will be nothing but file name of the updated permeability file (original permeability file name `PERM_IncludeFile_Initial` will be kept during history matching)

PERMFILE	`PERM_IncludeFile_Update, PERM_IncludeFile_Initial`

where:

`PERM_IncludeFile_Update`: Target File to be Replaced

`PERM_IncludeFile_Initial`: Original File to Replace Target File

-- EXAMPLE –

```
PERMFILE
-- Target   File to be Replaced (And Name of permability wrt. Iteration)
-- Original File to Replace Target File
PERMX.DATA PERMX_INI.DATA
/
```

PSOLVER

- This keyword specified linear matrix solver to find the root of the pressure equation. Direct method (DGESV) is preferred for small number of grid, such as less than 100 grids while iterative method (AMG) has advantages in computational time for large number of unknowns.

PSOLVER	Name of pressure linear matrix solver (DGESV, AMG, BiCG)

DGESV/
DGESV solver from CXML library on Compaq/Intel Fortran compiler.

AMG/
Algebric Multigrid Solver. Best performance for large scale matrix with symmetric component. Default solver for IMPES method.

BiCG/
Conjugate gradient based method. Applicable for most of non-symmetric matrices. Default solver for Fully Implicit method.

SL1DCON

- This keyword specifies the parameter of 1D saturation solver on streamline.

SL1DCON	SolMethod, NodeCtrl, Upwind, Compressibility, Gravity

where: [Red:Default]

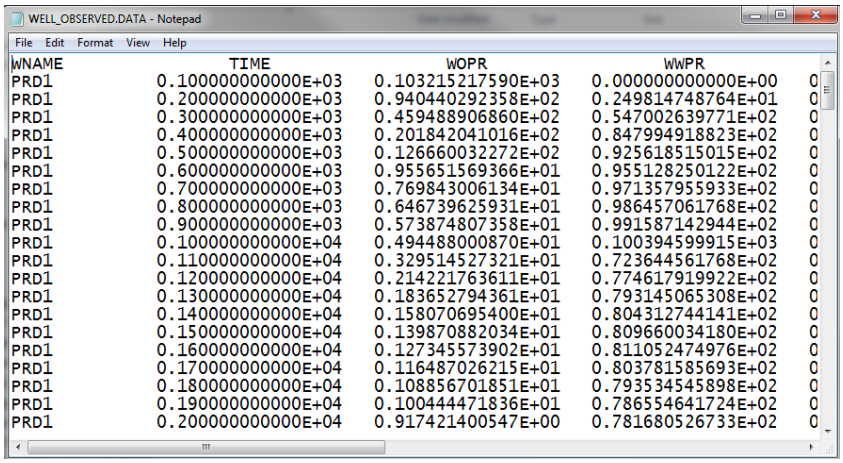
SolMethod:	Solution Method : Buckley-Leverett theory will be used for Analytical option, needs to careful for initial condition -> [Analytical,Explicit,Implicit]
NodeCtrl:	Node control method, REGular or IRRegular mesh. Auto will merge small TOF with adjacent node to improve CFL. -> [Reg,Irr,Auto]
Upwind:	Specify upwind option on 1-D Saturation Equation. Can use 1-3 point upstream weighting. -> [1PU,2PU,3PU]
Compressibility	Compressibility effect on streamline using effective density -> [Yes,No]
Gravity:	Gravity effects by operator splitting on Cartesian grids. -> [Yes,No]

-- EXAMPLE –

```
SL1DCON
EXPLICIT  REG SPU Yes Yes /
```

2.3.9 WELL_OBSRVED.DATA

This file is used to specify observed data during history-matching. External observation data is required if **well schedule is not assigned by WCONHIST/WCONINJH**. The format is text based observed data. The following figure is a example used for the history matching.



WNAME	TIME	WOPR	WWPR	
PRD1	0.100000000000E+03	0.103215217590E+03	0.000000000000E+00	0
PRD1	0.200000000000E+03	0.940440292358E+02	0.249814748764E+01	0
PRD1	0.300000000000E+03	0.459488906860E+02	0.547002639771E+02	0
PRD1	0.400000000000E+03	0.201842041016E+02	0.847994918823E+02	0
PRD1	0.500000000000E+03	0.126660032272E+02	0.925618515015E+02	0
PRD1	0.600000000000E+03	0.955651569366E+01	0.955128250122E+02	0
PRD1	0.700000000000E+03	0.769843006134E+01	0.971357955933E+02	0
PRD1	0.800000000000E+03	0.646739625931E+01	0.986457061768E+02	0
PRD1	0.900000000000E+03	0.573874807358E+01	0.991587142944E+02	0
PRD1	0.100000000000E+04	0.494488000870E+01	0.100394599915E+03	0
PRD1	0.110000000000E+04	0.329514527321E+01	0.723644561768E+02	0
PRD1	0.120000000000E+04	0.214221763611E+01	0.774617919922E+02	0
PRD1	0.130000000000E+04	0.183652794361E+01	0.793145065308E+02	0
PRD1	0.140000000000E+04	0.158070695400E+01	0.804312744141E+02	0
PRD1	0.150000000000E+04	0.139870882034E+01	0.809660034180E+02	0
PRD1	0.160000000000E+04	0.127345573902E+01	0.811052474976E+02	0
PRD1	0.170000000000E+04	0.116487026215E+01	0.803781585693E+02	0
PRD1	0.180000000000E+04	0.108856701851E+01	0.793534545898E+02	0
PRD1	0.190000000000E+04	0.100444471836E+01	0.786554641724E+02	0
PRD1	0.200000000000E+04	0.917421400547E+00	0.781680526733E+02	0

Figure. Example of WELL_OBSERVED.DATA

The format and requirement are summarized as follows.

- 1st line contains the header keyword. 1st and 2nd keywords must be well name and observed time. Then follows the data by arbitrary order.

- The all usable keywords are: '**WWPR**' '**WOPR**' '**WBHP**' '**WWCT**' .
  WWPR : water production rate, [STB/day]
  WOPR : oil production rate, [STB/day]
  WBHP : observed bottom hole pressure, [psi]
  WWCT : production water cut, [-]
  The WOPR/WWPR or WWCT is the minimum requirement to execute inversion module. (e.g. if only bottom hole pressure matching required, then dummy values need to be assigned for the well rate). It is recommend to assign water and oil rate with pressure data. If WWCT is given, these information are used for the travel time matching and thus overwrite the water-cut from given WWPR and WOPR.

- If data is missing, user can delete the row and TRACE3D will interoperate linearly to find the objective function.

- It is ok to provide well data in any order, however, **it is recommended to assign ascending order by observed TIME.**

- if **WCONHIST/WCONINJH** is given in input data, then the WELL_OBSERVED.DATA will be replaced during history matching process.

2.4 Details of output data and files

Various file names and definitions for the output files are listed in the section 2.1. In this section a brief overview of these output files and ways to visualize them are discussed. Recall that .out files are available after simulation only if Op8 of the OUTPUTS3D keyword is activated (= 1).

1. **S3D_Run_Production.out**: This output file gives the output of water cut and oil production data as a function of time for each well. First column is the time step, second column is the water cut data and third column is the oil production data for the producer number 1, then fourth and fifth columns give the water cut and oil production data respectively for the producer number 2 and so on for the other producers. This file can be directly taken to the EXCEL SPREAD SHEET to make a plot of the water cut and oil rate against time in days for all producing wells.

2. **S3D_Run_TauXXX.out**: This output file gives the time of flight at each grid block. This file can be taken directly to TECPLOT to make a plot of the time-of-flight contours. Note that this file is **not** available for an inversion run. An example time-of-flight contour plot has been shown in the figure below.

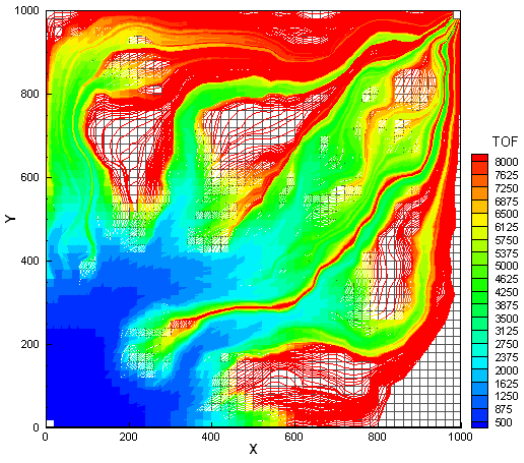


Figure 1-Time-of-Flight distribution for a heterogeneous Quarter 5 spot

3. **S3D_Run_Streamline.out:** This is the output file for plotting the streamlines in 2D or 3D with color codes showing the injector-producer relations and injection rate allocations (see ratealloc.out for numerical values). This output file can be directly taken to TECPLOT for plotting the streamlines in 3D or 2D. An example of the

streamline plot for a field case with arbitrary well pattern has been shown in the next figure.

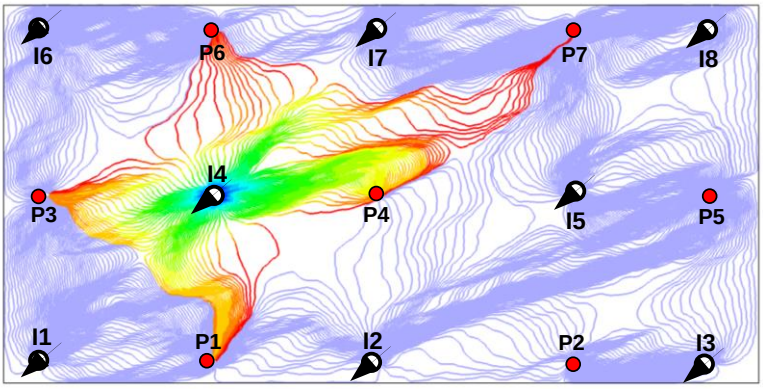


Figure 2- Streamline plot(X-Y view) for a 3D field case with arbitrary well pattern

4. **S3D_Run_EndSwat.out:** This output file gives the water saturation distribution for each grid blocks at the final time step for the semi-analytical option. This output can directly be taken to the TECPLOT for plotting the saturation distribution.

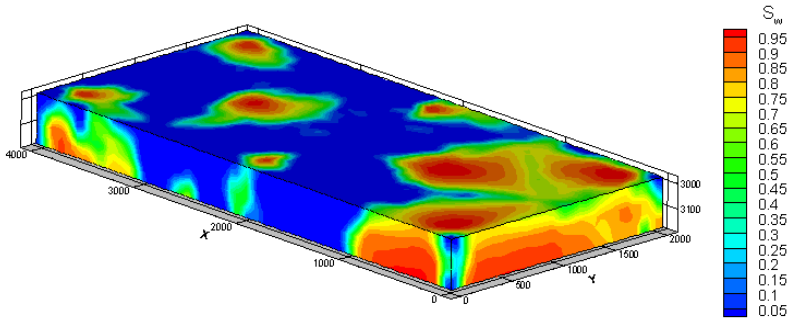


Figure 3- Saturation distribution for a 3-D field case at certain time

5. **S3D_Run_IniSwat.out:** This output file also gives the saturation distribution at the beginning of the time step.

6. **S3D_Run_RateAllocation.out:** This output file gives the rate allocation for each injector to each producer. The output is given at each pressure update time and also for each infill drilling.

7. **S3D_Run_Recovery.out:** This output file gives the recovery (fraction of original oil in place recovered) at each time step.

- The following files are given inside "Output" folder, under inside working directly. Note that 'OUTPUTS3D' needs to be specified to have these files.

8. *.plt:** Output saturation, pressure, or initial condition by Tecplot format.

9. *.xls:** Output saturation, pressure by Excel format.

10. WELL_*.xls:** Output well BHP, production rate, saturation, pressure, density, viscosity of well/well block.

11. PMATRIX_XXX.xls: Output pressure matrix for every time-step and iteration, by Excel if you use direct matrix solver, or text file for iterative solver.

12. SMATRIX_XXX.xls: Output saturation matrix for every saturation time level with iteration, only if you use implicit saturation solver.

13. STREAMLINE_Time_XXX.xls: Output streamlines for every time step, by Tecplot format.

3. Technical References

1. 1. Datta-Gupta, A. and King, M. J., Streamline Simulation: Theory and Practice, SPE Textbook Series, Vol. 11 (2007). 394p
2. Datta-Gupta, A. and King, M.J.: "A Semianalytical Approach to Tracer Flow Modeling in Heterogeneous Permeable Media," Advances in Water Resources, 18(1), 9, pp189-24, (1995).
3. King, M. J. and Datta-Gupta, A., "Streamline Simulation: A Current Perspective," In Situ, 22 (1), (1998).
4. Datta-Gupta, A., "Streamline Simulation: A Technology Update," SPE Distinguished Author Series, Journal of Petroleum Technology, 68-73 (December 2000).
5. Cheng, H., Osako, I., Datta-Gupta, A. and King, M. J. "A Rigorous Compressible Streamline Formulation for Two and Three Phase Black Oil Simulation," SPE Journal, 11(4), December 2006, p407-417.

4. Disclaimer and Copyright information

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5. Appendix : Sample Datafiles

RESERVOIR.DATA

```
--*****************                            ******************
--*****************  RESERVOIR DATA SECTION  ******************
--*****************                            ******************

----------------------------------------------------------------------
RUNSPEC - General Information
----------------------------------------------------------------------


DIMENS
   3    3    3  /


OIL

WATER

----------------------------------------------------------------------
GRID - Input Reservoir properties here
----------------------------------------------------------------------

DX
3*60.0 /

DY
3*60.0 /

DZ
20 10 30 /


PORO
27*0.2 /

PERMX
27*200 /

PERMY
27*200 /

PERMZ
27*20 /
/

TOPS
9*2995/


----------------------------------------------------------------------
PROPS - Input Fluid./.Rock properties here
----------------------------------------------------------------------
```

```
PVDO
-- PVT properties of dead oil-----
-- pres/   FVF/   oil viscosity/
14.6   1            1
10000  0.898998     1
/


PVTW
-- Water PVT function-----
--  Depth  Bw      Comp   Vw    Cv
--  Pres./     FVF/   comp/ vis at ref Pres/    viscosibil/
4000.00     1.00341   3.0d-6     0.96 0.0/


DENSITY
-- This is Deafault/
--     oil/    water/
--      37      62.3  /
        45.0  63.02    /


SWOF
--    Sw      Krw     Krow     Pcow
0.00000 0.00000 1.00000 0.00000
0.10000 0.01000 0.81000 0.00000
0.20000 0.04000 0.64000 0.00000
0.30000 0.09000 0.49000 0.00000
0.40000 0.16000 0.36000 0.00000
0.50000 0.25000 0.25000 0.00000
0.60000 0.36000 0.16000 0.00000
0.70000 0.49000 0.09000 0.00000
0.80000 0.64000 0.04000 0.00000
0.90000 0.81000 0.01000 0.00000
1.00000 1.00000 0.00000 0.00000
/


ROCK
4000 4.0d-6
/

----------------------------------------------------------------------
SOLUTION - Input Initial Condition here
----------------------------------------------------------------------

EQUIL
-- DATUM    DATUM     OWC
-- DEPTH    PRESS     DEPTH
   3000.    4000.     4000. /

--PRESSURE
--20*3000/

--SWAT
--20*0.0
--/


END
```

WELL.DATA

```
--*****************                          ******************
--*****************  WELL *FILE1* SECTION  ******************
--*****************                          ******************


WELSPEC
--                                                (BHP/RATE) (psi/bbl/Mscf) (Inj ->
WAT/GAS, Prd -> ORAT/GRAT/LRAT)
-- INJ/PRD  coord X*Y/  Z-Z/ Diameter/ Skin/ Condition/   Value/   Target/
      PRD1    41   41   1 1      0.25  0.d0         BHP    2500         /
      PRD2    1    41   1 1      0.25  0.d0         BHP    2500         /
      PRD3    41   1    1 1      0.25  0.d0         BHP    2500         /
      PRD4    1    1    1 1      0.25  0.d0         BHP    2500         /
      INJ     21   21   1 1      0.25  0.d0         RATE    500       WAT/
/



TSTEP
10*100
/


END
```

SIMULATION.DATA

```
--*****************                              ******************
--*****************  SIMULATION DATA SECTION  ******************
--*****************                              ******************

-----------------------------------------------------------------
Simulation data (Tuning Streamline information etc.)
-----------------------------------------------------------------



FDMETHOD
-- Numerical Method [SL/IMPES/FIM : Def = SL]
STREAMLINE


PSOLVER
-- Prs Lin Mtx Solver [SGAUSS/DGESV/ITGSV/CG/GMRES/AMG : Def = AMG]
AMG


SSOLVER
-- Sat Lin Mtx Solver on SL [SGAUSS/GBAND : Def = GBAND]
GBAND


CONVERGE
-- Convergence criteria for pressure    [Def = 1.E-2]
-- Convergence criteria for sat for FIM [Def = 1.E-3]
1.d-2 1.d-4 /


NUMLINE
-- Number of streamline    [Def = MAX(Nx,Ny,Nz)*Nwell]
-- SL launching position   [INJ/PRD/CEL : Def = INJ]
-- Trace From missed block [Yes/No : Def = No]
500 INJ Yes /


SL1DCON
-- Numerical Method  [EXP/IMP/ANALYTICAL : Def = EXP]
-- Node control      [IRR/REG/AUTO : Def = IRR]
-- Node Factor       [Def = 1.0]
-- Flow Upwind       [SPU/2PU/3PU : Def = SPU]
-- Compressibility   [Yes/No : Def = Yes]
-- Gravity flow      [Yes/No : Def = Yes]
ANALYTICAL  IRR 1.0 SPU Yes Yes /


CFL
-- CFL number, for explicit [Def = 1.0]
-- Minimum CFL time         [Def = 1.E-3]
0.5 1.d-3 /

CFLG
-- CFL number, for Grv&Pc   [Def = 1.0]
```

```
-- Minimum CFL time         [Def = 1.E-3]
1.0 1.d-3 /


OPTIONS3D
-- Pressure Update Freq [Def = 1, update every step, 0 = first ony]
-- Output CPG with Fault  (Heavy File)          [Def = 0, Normal out]
-- Use upstream Pressure of Trans Calc          [Def = 0, Use upstream]
-- Pres/WCT Sensitivity Output                  [Def = 0, no output]
1 0 0 0/


OUTPUTS3D
-- Output Debug
-- Output Block inf by Excel
-- Output Block inf by Tecplot
-- Output Streamline
-- Output Streamline with Diffusive TOF
-- Output Pressure Matrix
-- Output Saturation Matrix
-- Output S3D Interface View
-- Output S3D Inversion
-- Output Streamline by .SLN file
1 0 0 0 0 0 0 1 1 1 /



--*****************                            ******************
--*****************  SPECIFY INVERSION DATA ******************
--*****************                            ******************



DOINV
-- [TTM,AMP] Travel Time Inversion or Amplitude Inversion
-- [LSQ,GNN] LSQR minimization module or GaussNewton Method
-- Number of iteration for inversion
TTM LSQ 5 /


OBJINV
-- [0 >] Match WCT/GOR (1 = 100 multiplication to wSNS)
-- [0 >] Match BHP     (1 = 100 multiplication to pSNS)
1.0 0.0
/



OPTINV
-- [0 >] Lim of Param Update, Global scale (1 = less than 100% per step), WCT,
Def = 0
-- [0 >] Lim of Param Update, Grid   scale (1 = less than 100% per step), WCT,
Def = 0
-- [0 >] Lim of Param Update, Global scale (1 = less than 100% per step), BHP,
Def = 0
-- [0 >] Lim of Param Update, Grid   scale (1 = less than 100% per step), BHP,
Def = 0
-- [0 >] Give Constraint Before LSQR, by predicting dlnk in average sens, WCT,
Def = 2
-- [0 >] Give Constraint Before LSQR, by predicting dlnk in average sens, BHP,
Def = 2
2.0 2.0 0.0 1.0/
```

```
MAXPARAM
-- Maximum updated Parameter [Def = Maximum Prior]
1*
/


MINPARAM
-- Maximum updated Parameter [Def = Minimum Prior]
1*
/


MISFCRIT
-- WCT(TTime) Misfit Criteria(Dont inv below this number) [Def = 10.0]
-- BHP        Misfit Criteria(Dont inv below this number) [Def = 10.0]
2*
/


AVGSENS
-- Moving average sensitivity WCT [Def = 2]
-- Moving average sensitivity BHP [Def = 5]
2*
/


UPWELGRD
-- Do you want to update well grid param?
-- [Def = 1.0], below zero will not update
2*
/


LSQOPT
-- MxIte NormConst SmthCstH SmthCstV
-- [Def = 400,0,0,0]
4*
/



END
```

WELL_OBSERVED.DATA

WNAME	TIME	WOPR	WWPR	WGPR	WBHP	WWCT
PRD1	0.100000000000E+03	0.103215217590E+03	0.000000000000E+00	0.000000000000E+00	0.250000000000E+04	0.000000000000E+00
PRD1	0.200000000000E+03	0.940440292358E+02	0.249814748764E+01	0.000000000000E+00	0.250000000000E+04	0.258762296289E-01
PRD1	0.300000000000E+03	0.459488906860E+02	0.547002639771E+02	0.000000000000E+00	0.250000000000E+04	0.543474614620E+00
PRD1	0.400000000000E+03	0.201842041016E+02	0.847994918823E+02	0.000000000000E+00	0.250000000000E+04	0.807739615440E+00
PRD1	0.500000000000E+03	0.126660032272E+02	0.925618515015E+02	0.000000000000E+00	0.250000000000E+04	0.879632592201E+00
PRD1	0.600000000000E+03	0.955651569366E+01	0.955128250122E+02	0.000000000000E+00	0.250000000000E+04	0.909045636654E+00
PRD1	0.700000000000E+03	0.769843006134E+01	0.971357955933E+02	0.000000000000E+00	0.250000000000E+04	0.926565706730E+00
PRD1	0.800000000000E+03	0.646739625931E+01	0.986457061768E+02	0.000000000000E+00	0.250000000000E+04	0.938472032547E+00
PRD1	0.900000000000E+03	0.573874807358E+01	0.991587142944E+02	0.000000000000E+00	0.250000000000E+04	0.945291817188E+00
PRD1	0.100000000000E+04	0.494488000870E+01	0.100394599915E+03	0.000000000000E+00	0.250000000000E+04	0.953057706356E+00
PRD1	0.110000000000E+04	0.329514527321E+01	0.723644561768E+02	0.000000000000E+00	0.250000000000E+04	0.956447780132E+00
PRD1	0.120000000000E+04	0.214221763611E+01	0.774617919922E+02	0.000000000000E+00	0.250000000000E+04	0.973089098930E+00
PRD1	0.130000000000E+04	0.183652794361E+01	0.793145065308E+02	0.000000000000E+00	0.250000000000E+04	0.977369010448E+00
PRD1	0.140000000000E+04	0.158070695400E+01	0.804312744141E+02	0.000000000000E+00	0.250000000000E+04	0.980725884438E+00
PRD1	0.150000000000E+04	0.139870882034E+01	0.809660034180E+02	0.000000000000E+00	0.250000000000E+04	0.983018100262E+00
PRD1	0.160000000000E+04	0.127345573902E+01	0.811052474976E+02	0.000000000000E+00	0.250000000000E+04	0.984541416168E+00
PRD1	0.170000000000E+04	0.116487026215E+01	0.803781585693E+02	0.000000000000E+00	0.250000000000E+04	0.985714673996E+00
PRD1	0.180000000000E+04	0.108856701851E+01	0.793534545898E+02	0.000000000000E+00	0.250000000000E+04	0.986467659473E+00
PRD1	0.190000000000E+04	0.100444471836E+01	0.786554641724E+02	0.000000000000E+00	0.250000000000E+04	0.987390816212E+00
PRD1	0.200000000000E+04	0.917421400547E+00	0.781680526733E+02	0.000000000000E+00	0.250000000000E+04	0.988399624825E+00
PRD2	0.100000000000E+03	0.293357982635E+02	0.000000000000E+00	0.000000000000E+00	0.250000000000E+04	0.000000000000E+00
PRD2	0.200000000000E+03	0.299279060364E+02	0.244819043510E-10	0.000000000000E+00	0.250000000000E+04	0.818029292308E-12
PRD2	0.300000000000E+03	0.330508193970E+02	0.378435743187E-06	0.000000000000E+00	0.250000000000E+04	0.114501164106E-07
PRD2	0.400000000000E+03	0.285918750763E+02	0.456159730675E-03	0.000000000000E+00	0.250000000000E+04	0.159539195010E-04
PRD2	0.500000000000E+03	0.251342124939E+02	0.239775255322E-01	0.000000000000E+00	0.250000000000E+04	0.953070411924E-03
PRD2	0.600000000000E+03	0.220932464600E+02	0.462576597929E+00	0.000000000000E+00	0.250000000000E+04	0.205080788583E-01
PRD2	0.700000000000E+03	0.186152496338E+02	0.226513957977E+01	0.000000000000E+00	0.250000000000E+04	0.108481675386E+00
PRD2	0.800000000000E+03	0.149423637390E+02	0.508381128311E+01	0.000000000000E+00	0.250000000000E+04	0.253858327866E+00
PRD2	0.900000000000E+03	0.115440454483E+02	0.806184959412E+01	0.000000000000E+00	0.250000000000E+04	0.411195188761E+00
PRD2	0.100000000000E+04	0.907608032227E+01	0.103350563049E+02	0.000000000000E+00	0.250000000000E+04	0.532429218292E+00
PRD2	0.110000000000E+04	0.500674533844E+01	0.891888523102E+01	0.000000000000E+00	0.250000000000E+04	0.640465438366E+00
PRD2	0.120000000000E+04	0.430503511429E+01	0.974798011780E+01	0.000000000000E+00	0.250000000000E+04	0.693657577038E+00
PRD2	0.130000000000E+04	0.368729972839E+01	0.106066312790E+02	0.000000000000E+00	0.250000000000E+04	0.742037415504E+00
PRD2	0.140000000000E+04	0.313961911201E+01	0.114505119324E+02	0.000000000000E+00	0.250000000000E+04	0.784812152386E+00
PRD2	0.150000000000E+04	0.273826742172E+01	0.122500591278E+02	0.000000000000E+00	0.250000000000E+04	0.817306637764E+00