# SensorPlot Manual

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## Program Description

**SensorPlot** is a post-processor program, which converts **Sensor** result files for graphical analysis with X-Y plotting application **Plot2Excel**. You can select data for plotting, compare multiple simulation runs, add observed data, make unit conversions and display results in MS Excel in a very quick fashion.

A Sensor reservoir simulation run creates a binary result file "fort.61" containing calculated data for wells, platforms, regions, superregions, total field and traced components. (See format of the write statements in page11). SensorPlot includes the following capabilities to handle this data:

- Convert the entire result file in Tab-delimited text form importable in MS Excel or any other spreadsheet type of program.
- Select data for X-Y plotting with Plot2Excel. These commands create two tab-delimited text files. One contains selected data tables (*.tab) and is referred to as the data table file. The other contains plot-log information (*.plt) and is referred to as the plot-log file. Both files are used with Plot2Excel to automatically build these plots in MS Excel.
- You can specify any number of Sensor result files to display the selected variables on the same plot. On the combined plots, different colors indicate each data source.
- Add observed data for automatic plotting. Observed data is plotted in slightly larger symbols than calculated results and without connecting lines.
- Make unit conversions for Sensor results and observed data with user-specified unit names and coefficient factors.

### Running SensorPlot

SensorPlot input is a text file controlled by a set of keywords. Each keyword is described on the following chapter. On the page 9 you can see guidance for the program run and viewing the plots with Plot2Excel.

SensorPlot writes a summary file "SensorPlot.inf" to show the results or errors messages produced by every run. In addition, a table summary is printed at the end of each output data table file.

## SensorPlot Keywords

**TITLE & ENDTITLE**

All text lines contained between these two keywords are printed at the top of the output data table and plot-log files.

```
TITLE
  Study of grid refinement in full field model
  Grid  100 x 100 x 25
ENDTITLE
```

**FILE**

Two or three entries are expected on each line under this keyword:

- Name of the Sensor result file (fort.61) with up to 120 characters.
- Source name (a single word) to be printed on plot legends to represent each simulation run. The source name can include up to 24 characters.
- (Optional) frequency reduction value. Default is 1.

The number of files is not limited. File and source names must not repeat.

```
FILE
  FORT.61A  RUNA_IMPLICIT
  FORT.61B  RUNB_IMPES        5
```

Note: The frequency reduction value allows printing only each n-th time value from the Sensor result file. Omit it if you want to plot every time step. In the above example, SensorPlot will use FORT.61B file results only for the time steps 1, 5, 10, 15, etc. This reduces the length of the Excel data tables by a factor of 5. The keyword is provided to handle the following limitation:

MS Excel worksheets may contain maximum 65,536 rows of data. Generally it provides plenty of storage space for all data tables. Nevertheless, data overflow problems may occur if too many plots are requested, and/or too many time steps are reported (as defined in the TIME vector, written to the fort.61 file by Sensor). SensorPlot has a built-in limitation to print only 65,500 lines in an output data table file. If the requested amount of data exceeds this limit the program stops printing the file giving a warning message.

**OUTPUTNAME**

Sets the base name for output files with data tables and plot-log records (up to 120 characters). These output files will get corresponding extensions (.tab) and (.plt) by default. Notice that the new file overwrites the existing file with the same name.

```
OUTPUTNAME
  TESTRUN
```

In this example the complete output file names are `"TESTRUN.TAB"` and `"TESTRUN.PLT"`.

**WELL, PLATFORM, REGION, SUPERREGION, FIELD**

The above keywords instruct SensorPlot to write text data tables and plot-log records used to build series of charts with Plot2Excel. The format of these statements is demonstrated by the following examples:

```
WELL W8301
   QOIL QWAT

WELL W8101 - W8110
   QOIL GOR  (Y2) WCUT
   QWI  (Y2) PBH
   QGI  (Y2) CUMGI

WELL W8201
   (X) CUMOIL (Y1) QOIL GOR (Y2) PGRID PBH (T) HISTORY MATCH

PLATFORM 1 - 2
   QOIL QGAS QWAT (Y2) WCUT

REGION 1 - 4
   QOIL QWAT QGAS  (Y2) WCUT OILREC GASREC

SUPERREGION 1 - 2
   QOIL QWAT QGAS  (Y2) WCUT OILREC GASREC

FIELD
   QOIL QWAT QGAS (Y2) WCUT OILREC GASREC
   (X) PAVG (Y1) QOIL GOR (Y2) OILREC WCUT
```

See the last page 13 for a complete list of variables which can be plotted.

Keyword WELL must be followed by a single well name or a range of names separated by a dash. If the range of names is used a plot is built for each well in the range. SensorPlot compares well names with the list of names in the first result file specified under FILE and if they do not match it returns an error message.

Keywords PLATFORM, REGION and SUPERREGION must be followed by an integer or a range of integers separated by a dash. A plot is built for each element of the range. You should take care that the specified integers match actual numbers in the result files.

Keyword FIELD must not be followed by any symbols on the same line.

TIME is the default X-variable for all plots. You can change the X-variable to anything you need like CUMOIL, PAVG etc, using the (X) parameter as the first symbol on the plot line.

By default all Y-variables are plotted on the primary Y-axis, which is on the left side. Parameter (Y1) must be used only if X- variable is changed with (X). If more then one variable should appear on the same plot the secondary Y-axis can be applied for this purpose. (Y2) parameter serves to place variables following it on the secondary Y-axis.

SensorPlot gives a comprehensive default title to every plot. Use the (T) parameter to override the default title. Any characters following it will be printed as the plot title.

**TRACER**

This keyword creates plots of tracer fractions for individual wells or blocks. Plots of tracer fractions are created with the data from the first file in the list under FILE. Other files cannot be used for this purpose.

```
TRACER
  W8101   C1    (T) Tracing methane in well W8101
  W8301 - W8310     WATR
  COMPANY1 - COMPANY4      OIL
  COMPANY3   GAS
```

Keyword TRACER must stand alone on a line. The first entry on the plot line is a well or block name or a range of names separated by a dash. A plot is created for each element in the range. The second entry on the plot line is the name of a traced component. SensorPlot checks if the specified wells and block names match to the list of names in the first result file and if they do not match it returns an error message.

The only optional parameter on the plot line is (T) that can be used to override the default title for the plot. Any symbols following the (T) parameter will be printed as the plot title.

**UNITS**

This keyword sets unit names and conversion coefficients for printing Sensor results and user data.

```
UNITS
TIME    YEARS       .0027378
QOIL    MSTB/D      .001        .001
QWAT    MSTB/D      .001        .001
QGAS    MMCF/D      .001        .001
GOR     MCF/STB     .001
WCUT    FR          .01
```

The first number in the line is a conversion coefficient for Sensor results. The second number is a coefficient to multiply user data. Both coefficients have default values of 1.0. Giving to TIME a unit name “YEAR” triggers the use of calendar year on the plot time axis. See the last page 13 for a list of the default units of Sensor results.

**XTIME**

This keyword can be used to set the min and max values for X-axis in all plots that have TIME as an X-parameter. It can help you to display only the time period that represents interest in your simulations. Two positive numbers for the beginning and the end of the time period follow the keyword. Example:

```
XTIME  366  730
```

Take care that the unit of these values match the unit of TIME vector.

**WELLDATA PLATFORMDATA REGIONDATA SUPRREGDATA FIELDDATA**

These keywords provide an option to supply user (observed) data that can be plotted along with the Sensor calculated results on corresponding plots.

```
FIELDDATA
TIME  QOIL   GOR   WCUT
180   60000  -101  30.0
365   50000  -101  35.0
730   46000  -101  46.0
1825  34000  3500  58.0
3650  20000  4500  66.0

WELLDATA
W8201
SOURCE  OPERATOR_DATA
TIME  QOIL   GOR   WCUT  PBH
180   1500   1500  30.0  3500
365   1500   1700  35.0  3300
730   1200   2200  46.0  3200
1825  1000   3500  58.0  2800

W8302
SOURCE  OPERATOR_DATA
TIME  QOIL   GOR   WCUT  PBH
180   1500   1500  30.0  3500
365   1500   1700  35.0  3300

PLATFORMDATA
1
TIME  QOIL   GOR   WCUT  QWI
180   7500   1500  30.0  3000
365   5500   1700  35.0  3000

2
TIME  QOIL   GOR   WCUT  QWI
180   7500   1500  30.0  3000
365   5500   1700  35.0  3000
```

FIELDDATA may contain only one data table. Other keywords may have several tables preceded by the well name or index for platforms, regions or superregions.

SOURCE is an optional parameter that can appear after the table name to override the default source name, which is “OBSERVED”.

Names of all data variables must be valid for each particular data type. The number of data entries in each line must equal the number of data names. Should some point be missing in the user data, it must be given as a number less then (-100).

TIME in the user data must be entered as a single positive number of days, months, years etc. If you want to plot Sensor results and observed data with calendar time, enter the user time vector as years with fractional part like 1997.75. The fraction should be a number of days from the beginning of the year divided by the total number of days in this year. Then change the unit of time vector in Sensor results (which is days by default) with conversion coefficient = 1 / 365.25.

```
UNITS
 TIME  YEAR    0.0027378   1.0
 ...
```

Note that SensorPlot can read up to 132 characters on a line. User data entries should not exceed this limit otherwise it will be truncated.

**PRINTALL**

Convert the entire result file into Tab-delimited text form importable in Plot2Excel or any spreadsheet type of program. Three or four entries are expected on each line under this keyword:

1. Name of the Sensor result file (fort.61).
2. Source name to represent each simulation run with up to 24 characters.
3. Complete name of output text file.
4. (Optional) frequency reduction value. Default is 1. (see Note for FILE keyword)

The number of files for full printout is not limited.

```
PRINTALL
      FORT.61A    RUNA_IMPLICIT     FORT61A_ALL.TAB
      FORT.61B    RUNB_IMPES        FORT61B_ALL.TAB   5
```

**COLORS**

SensorPlot applies different colors to distinguish different data sources when multiple simulation runs are compared. Variables from one file are plotted in the same color. There are 7 colors in the following sequence:

```
/ BLUE, PINK, GOLD, GREEN, RED, BLACK, GREY /
```

By default, BLUE color is picked for data from the first file, PINK for data from the second file and so on. If there are more than 7 data sources, the color sequence is repeated. You cannot add new colors to the set, but you can change the order in with they are selected by SensorPlot using keyword COLORS.

```
COLORS   BLACK GREY BLUE RED GREEN GOLD PINK
```

Color names can be repeated. The number of color entries must be in the range from 1 to 7.

**NOSYMBOLS**

This keyword can be used to produce line plots with no symbols. It does not effect observed data and plots of tracer fractions. The keyword has no arguments and can appear several times. It must be entered before the requested plots. In this case each plotted variable is distinguished only by different color.

**SYMBOLS**

Symbols are used to distinguish lines of different variables on the same plot. The default set of symbols is:

```
/ CIR, DIA, TRI, SQU /
```

which stand for circle, diamond, triangle and square. The first 4 variables are plotted with solid symbols, after that the sequence of symbols repeats having white center fill. The default symbol size is 5.

This keyword has two functions. The first one is to disable effect of the keyword NOSYMBOLS which was entered above. For this case no arguments are needed.

```
SYMBOLS
```

The second functions is to change the order of symbols and their size as shown in the example:

```
SYMBOLS   DIA TRI CIR SQU  7
```

Symbol names can be repeated. A number of symbol arguments must be in the range from 1 to 4. An integer on the same line can set the size of symbols and it must be from 2 to 12. Multiple entries of the keyword are allowed.

**END**

Stop the reading of the input file.

Throughout the input file, SensorPlot ignores blank lines, comment lines and any characters following the symbol “!” on any line. A comment line is a line that has “C” as the first nonblank character followed by at least one blank.

## Example Input Data Set.

```
TITLE
  SensorPlot example data set
ENDTITLE

FILE
  FORT.61A    RUNA
  FORT.61B    RUNB   5

OUTPUTNAME
  TESTAB      ! to name files "TESTAB.TAB" and "TESTAB.PLT"

PRINTALL
  FORT.61A    RUNA   RUNA_ALL.TAB

WELL W8101 - W8110
  QOIL GOR  (Y2) WCUT

WELL W8101
  (X) CUMOIL (Y1) QOIL GOR (Y2) PGRID PBH (T) HISTORY MATCH

WELL W8301W – W8306W
  QWI (Y2) CUMWI

PLATFORM 1 - 2
  QOIL GOR (Y2) WCUT
  CUMOIL CUMWAT (Y2) CUMGAS

REGION 1 - 4
  QOIL QWAT QGAS  (Y2) OILREC GASREC

SUPERREGION 1
  QOIL QWAT QGAS (Y2) OILREC GASREC

FIELD
  QOIL QWAT QGAS (Y2) WCUT OILREC
  (X) PAVG (Y1) QOIL GOR (Y2) WCUT

TRACER
  W8101 - W8110 WATR

UNITS
  TIME        YEARS         .0027378      1.
  QOIL        MSTB/D        .001          1.
  QWAT        MSTB/D        .001          1.
  CUMOIL      MMSTB         .001          1.

FIELDDATA
  SOURCE  Operator_Data
  TIME  QOIL   GOR   WCUT
  0.5    40.0   650    0.0
  1.0    40.0   650    5
  1.5    33.2   930    15
  2.0    28.5   1200   25
  2.5    24.0   1400   42
  3.0    20.9   1550   57
END
```

## Guidance for Creating Plots from Sensor Results

We illustrate the example of Sensor run with an input file **spe1.dat**. The files can be downloaded from the website www.coatsengineering.com.

### 1. Run Sensor

Make sure the files **Sensor.exe** and **spe1.dat** are in the same directory.
In a DOS command prompt window type the directory's path and keyboard enter:

```
Sensor.exe < spe1.dat > spe1.out
```
(or any output file name you desire).

Move or rename **fort.61** to (say) "**f61spe1**". Change the **spe1.dat** datafile to allow no gas solution above bubble point (as indicated in comments in the **spe1.dat** datafile). Keyboard enter:

```
Sensor.exe < spe1a.dat > spe1a.out
```

Move or rename **fort.61** to (say) "**f61spe1a**".

### 2. Run SensorPlot

Construct the SensorPlot input file (say) "**spe1.sp**" as:

```
TITLE
  SPE1 compare cases of gas going into sol'n
  and not going into sol'n above 4014 psia bubble pt.
ENDTITLE

FILE
  f61spe1     Rs'>0
  f61spe1a    Rs'=0

OUTPUTNAME
  spe1       ! any name desired

FIELD
  QOIL   (Y2) GOR    (T) SPE1 EFFECT OF Rs SOLUTION GAS ABOVE BP
  CUMOIL (Y2) CUMGAS
  PAVG   (Y2) OILREC
END
```

Make sure the files **SensorPlot.exe**, **f61spe1**, **f61spe1a** and **spe1.sp** are in the same directory. Keyboard enter:

```
SensorPlot.exe
```

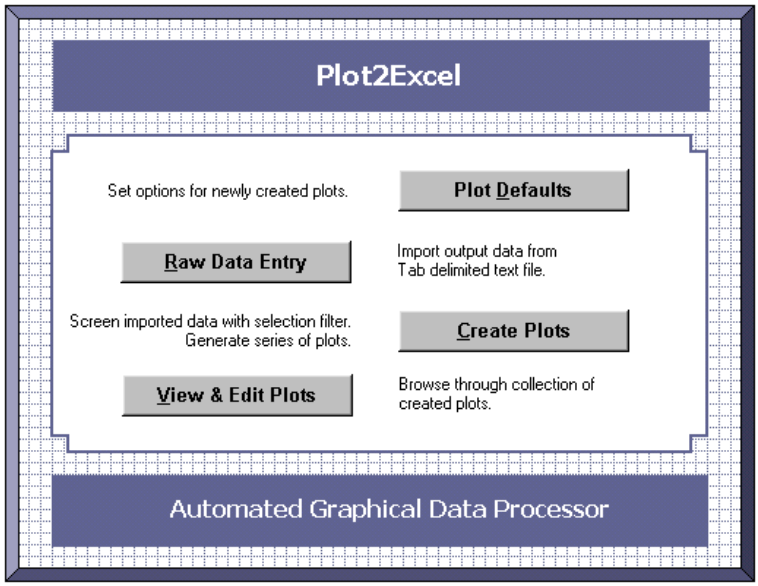
At the prompt, enter "**spe1.sp**". See file "**SensorPlot.inf**" for the run summary. SensorPlot will generate 2 files: "**spe1.tab**" with data tables and "**spe1.plt**" with plot-log records.

Note: If you are making many runs and always want the same plots, you can construct the ".sp" file once with the file name "fort.61" entered under file. Then after each run when you want plots, you need only keyboard enter "SensorPlot.exe" and proceed from there. The downloadable Sensor datafiles include SensorPlot datafiles of ".sp" extension for spe1,spe2,spe3,spe5,spe7,spe9,spe10, test2, test3a and test16.

### 3. Run Plot2Excel

The SensorPlot run produced a data tables file **spe1.tab** and a file with plot-log records **spe1.plt** for the requested plots. Having these two files, you need only a few mouse clicks to see the actual plots on your screen in the following way:

1) Start MS Excel. Open a file with Plot2Excel automation (Plot2Excel.xls).




2) On the worksheet called "Menu" click on the **Raw Data Entry** button.
3) Use the **Select Data Table File** button to find the file **spe1.tab**. Click on Open. On the same menu enter a name for the worksheet to import the data tables: "SPE1". Click on **OK** button to import a copy of the data tables on the selected worksheet.
4) Click on **Create Plots** button. In the Data Filter Menu click on the **Plot-Log Menu** button.
5) In the Plot-Log Menu use the **Load Plot-Log** button to find the file **spe1.plt**. Click on Open. Click **Yes** on the information box. Wait until the plot building is completed and close the Data Filter Menu.
6) To quickly view the plots click on the **View & Edit Plots** button to bring up the Plot View menu.

The **Plot Setup** menu offers an array of tools to edit all details of created plots. You can remove or add plotted variables, change colors, styles and size of lines and symbols, modify axis scale, titles and so on. You can also create new plots using the imported data tables, combine or cross-plot any variables and apply custom formats.

It is highly recommended to use MS Excel 2000 for running the Plot-Log function. The older version of Excel is prone to run out of memory and stop with a job of generating more then 15 plots at a time. Excel 2000 can build more than 100 plots at once.

## Format of Sensor X-Y Plot File, Fort.61

Sensor writes results to Unit 61 (file "fort.61") for xy plotting purposes. Results are included for wells, platforms, regions, superregions, total field, and tracer fractions. The user can write a program to read and process Unit 61 results as required for plotting by the plot package of his choice. This fort.61 file is the file used for Plot2Excel and listed under the keyword FILE of the SensorPlot interface program.

The Unit 61 file is written as follows (real variables are REAL*8):

```
CHARACTER KW*12, WELLNAME*8, WNAME(NWELLS)*8, CPTNAME*4, BLOCKNAME*8, NAME*8
REWIND (61)
WRITE (61) TIME1,TIME2,IDAY,IMONTH,IYEAR,NWELLS,NBLOCK,
   NTRACER,MAXNF,MAXLINE
WRITE (61) (WNAME(I),I=1,NWELLS)
WRITE (61) (BLOCKNAME(I),I=1,NBLOCK)
KW='WELL'
WRITE (61) KW,NW
DO IWELL=1,NW
   WRITE (61) WELLNAME,NLINES
   DO LINE=1,NLINES
     WRITE (61) (DATA(I),I=1,20)    ! VECTOR OF WELL RESULTS
   ENDDO
ENDDO
KW='PLATFORM'
WRITE (61) KW,NPLAT
DO IPLAT=1,NPLAT
  WRITE (61) IPLAT,NLINES
  DO LINE=1,NLINES
      WRITE (61) (DATA(I),I=1,18)    ! VECTOR OF PLATFORM RESULTS
   ENDDO
ENDDO
KW='REGION'
WRITE (61) KW,NREGION
DO IREG=1,NREGION
   WRITE (61) IREG,NLINES
   DO LINE=1,NLINES
      WRITE (61) (DATA(I),I=1,16)  ! VECTOR OF REGION RESULTS
   ENDDO
ENDDO
KW='SUPERREGION'
WRITE (61) K2,NSREGION
DO ISREG=1,NSREGION
   WRITE (61) ISREG,NLINES
   DO LINE=1,NLINES
      WRITE (61) (DATA(I),I=1,16)  ! VECTOR OF SUPERREGION RESULTS
   ENDDO
ENDDO
```

```
KW='FIELD'
WRITE (61) KW,NLINES
DO LINE=1,NLINES
    WRITE (61) (DATA(I),I=1,19)    ! VECTOR OF FIELD RESULTS
ENDDO
KW='TRACER'
DO L=1,NTRACER
   WRITE (61) KW,NAME,CPTNAME,NF,NLINES  ! NAME IS A WNAME OR A BLOCKNAME
   DO LINE=1,NLINES
      WRITE (61) TIME,(F(I),I=1,NF),(CUMF(I),I=1,NF)  ! TRACER FRACTIONS
   ENDDO
ENDDO
KW='END'
L=0
WRITE (61) KW,L
```

The vectors of results and default units of each variable are shown on the page 14.

For the first one-line write above,

```
TIME1    time at the start of the run, days
TIME2    time at the end of the run
IDAY     day of date at time=0 (1-31)
IMONTH   month of date at time=0 (1-12)
IYEAR    year of date at time=0 (e.g. 1978 1992 2004)
NWELLS   total number of wells
NTRACER  number of tracer data tables
MAXNF    maximum number of tracer fractions (6 or less)
MAXLINE  maximum number of lines in any data table
```

For a run starting from time = 0, TIME1 is 0. For a restart run starting from a previous run's restart record written at (say) time = 2400 days, TIME1 is 2400. If DATE is not entered in the Initial Data of the run starting at time=0, then IDAY, IMONTH, and IYEAR will be 0.

WNAME and WELLNAME are character*8 well names and CPTNAME is a character*4 component name. In the tracer results, NAME is either a well name or a block name, CPTNAME is the traced component name, and NF is the number of fractions for the traced component. F(i) and CUMF(i) are respectively the instantaneous and cumulative values of tracer fraction i, with values between 0 and 1.0.

The well results are controlled by Sensor keywords WELLSUM and SUMFREQ. The platform results are controlled by keywords PLATSUM and SUMFREQ. The region results are controlled by keywords REGSUM and SUMFREQ. The superregion results are controlled by keywords SREGSUM and SUMFREQ. The field results are controlled by keywords FIELDSUM and SUMFREQ. The tracer results, if any, are controlled by SUMFREQ.

## Variable Names in the Sensor Result File (Fort.61):

| # | WELL | PLATFORM | REGION | SUPERREGION | FIELD |
|---|---|---|---|---|---|
| 1 | TIME | X* | X | X | X |
| 2 | QOIL | X | X | X | X |
| 3 | QWAT | X | X | X | X |
| 4 | QGAS | X | X | X | X |
| 5 | QWI | X | X | X | X |
| 6 | QGI | X | X | X | X |
| 7 | WCUT | X | X | X | X |
| 8 | GOR | X | X | X | X |
| 9 | CUMOIL | X | X | X | X |
| 10 | CUMWAT | X | X | X | X |
| 11 | CUMGAS | X | X | X | X |
| 12 | CUMWI | X | X | X | X |
| 13 | CUMGI | X | X | X | X |
| 14 | QGLIFT | QGSALE | OILREC | OILREC | OILREC |
| 15 | CUMGLIFT | CUMGSALE | GASREC | GASREC | GASREC |
| 16 | SG | ONTIMEPR | PAVGHC | PAVGHC | PAVGHC |
| 17 | SW | ONTIMEWI | | | PAVG |
| 18 | PTH | ONTIMEGI | | | QGLIFT |
| 19 | PBH | | | | CUMGLIFT |
| 20 | PGRID | | | | |

* X denotes the same entries as under vector WELL

## Default Units in the Sensor Result Files:

| | |
|---|---|
| TIME | time, days |
| QOIL | oil production rate, stb/d |
| QWAT | water production rate, stb/d |
| QGAS | gas production rate, mcf/d |
| QWI | water injection rate, stb/d |
| QGI | gas injection rate, mcf/d |
| WCUT | water cut, % |
| GOR | gas-oil ratio, scf/stb |
| CUMOIL | cumulative oil production, mstb |
| CUMWAT | cumulative water production, mstb |
| CUMGAS | cumulative gas production, mmcf |
| CUMWI | cumulative water injection, mstb |
| CUMGI | cumulative gas injection, mmcf |
| QGLIFT | gaslift gas rate, mcf/d |
| CUMGLIFT | cumulative gaslift gas, mmcf |
| SG | grid block gas saturation at the bhp perf, fraction |
| SW | grid block water saturation at the bhp perf, fraction |
| PTH | tubinghead pressure, psia |
| PBH | bottomhole wellbore pressure at the bhp perf, psia |
| PGRID | grid block pressure at the bhp perf, psia |
| QGSALE | gas sale rate, mcf/d |
| CUMGSALE | cumulative gas sales, mmcf |
| ONTIMEPR | ontime for production, fraction |
| ONTIMEWI | ontime for water injection |
| ONTIMEGI | ontime for gas injection |
| OILREC | % recovery of oil initially in place in region |
| GASREC | % recovery of gas initially in place in region |
| PAVGHC | hydrocarbon pore volume average pressure, psia |
| PAVG | pore volume average, psia |