"Compositional Gas Reservoir Simulator with Mobility Control Options"
UT-DOECO2
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User's Guide

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Table of Contents

1 INTRODUCTION

This User's Guide is intended to provide a general description of DOECO2 reservoir simulator and its input parameters. For any detailed background information, users may refer to the accompanying the technical reports.

1.1 UT-DOECO2 Model Description

The main features currently available are summarized as follows:

- Three-dimensional
- Compositional equation-of-state
- IMPES formulation
- Three-phase flash calculation capability
- Higher-order TVD finite-difference method
- Full physical dispersion tensor
- Vertical and horizontal wells capability
- Tracer flood
- Polymer flood
- Dilute-surfactant option
- Several solvers and preconditioners

UT-DOECO2 is based on an isothermal, three-dimensional, compositional simulator for miscible gas flooding developed at the University of Texas at Austin called UTCOMP. The formulation is based on Acs formulation [C1]. The solution scheme is analogous to IMPES. First, the gridblock pressure is solved for implicitly using explicit dating of saturation-dependent terms. The material balance equations are solved explicitly for the overall concentration of each component in moles. Phase compositions are obtained by flash calculations [P2, P3]. A rigorous Gibbs stability test is performed before all flash calculations to determine the number of phases [P2, P3]; a phase identification test is done after all flashes in order to consistently label each phase for subsequent property calculation [P2, P4]. The non-aqueous fluid properties are modeled using the Peng-Robinson equation of state (PRES) [P1] or a modified version of the Redlich-Kwong equation of state (RKES) [T1]. The phases which may flow simultaneously are: (1) aqueous phase, (2) oil phase, (3) gas phase, and (4) a second, non-aqueous liquid. Water is allowed only in the aqueous phase. A volume shift parameter option, based on the work of Jhaveri and Youngren [J1], was implemented to adjust the liquid densities. The volume shift parameter is totally excluded from fugacity and fugacity-derivative calculations, and hence, it does not affect flash

calculations, i.e., both phase compositions and amounts remain unaffected, and only the liquid densities are adjusted after flash calculations have been performed.

A higher-order finite difference with a flux limiter method is used for numerical dispersion and grid orientation control [C2, L1]. Physical dispersion is modeled using the full dispersion tensor, and the elements of the dispersion tensor contain contributions from two sources: molecular diffusion and mechanical dispersion. Tracer option is also added. The assumption for the tracer material balance is that the tracers do not change the phase behavior of the non-tracer components. Features of this option include dispersion, adsorption, radioactive decay, partitioning, and capacitance.

A dilute-surfactant option is added to model foam for mobility control. The dilute-surfactant option is also implemented as an extension of the tracer option. The following three main features have been implemented with the dilute-surfactant option:

- hydrocarbon components can be dissolved into the aqueous phase according to the surfactant concentration using either the equilibrium K-value or the kinetic mass transfer method;
- interfacial tension is calculated as a function of the solubilization factor using the Healy and Reed (1975) model or the modified Huh (1979) model; and
- additional tracer adsorption option which allows the adsorption to be reversible to salinity but irreversible to concentration.

Several model options include 1) P_C^* model by Cheng *et al.*, [C1], 2) Table look up for resistance factor, and 3) a fully coupled formulation of the two-phase foam using local-equilibrium approximation based on Chen et al. [C3].

For CO_2 sequestration in deep saline reservoirs, the interaction between brine and CO_2 has been added. To improve vapor pressure prediction of water (and solubility of water in the non-aqueous phase), a correction term, α (Soreide-Whitson, 1992) is used with the EOS constant a. The effect of salinity on the solubility of CO_2 in brine is modeled by adjusting the binary interaction coefficients in the Peng-Robinson EOS. For viscosity the critical volume of H_2O and for density the computed Peng Robinson EOS density are modified for salinity. A salinity correction for the solubility of CO_2 in brine is also added to the existing implementation of Henry's law to simulate CO_2 injection for EOR. An empirical correlation taken from Whitson and Brule (2000) is used to

calculate the ratio of solubilities in pure water and saline water.

Additional enhancements are highlighted as follows:

- Geomechanics option
- General three-phase relative permeability with hysteresis
- Foam flood capability using two foam models
- Corner point grid geometry option
- Visualization using Sciencesoft software, S3graf

The geomechanics model was implemented; the fluid-solid coupling procedure is similar to the procedure in Chen *et al.* [C4] and Gai [G1]. The model consists of fluid flow mass conservation law and solid phase mass conservation law. The pressure equation in the coupled fluid and solid system facilitates the development of an iterative scheme solving the coupled system by utilizing compositional flow simulator and solving the linear poroelasticity force equilibrium equation as an additional module. For linear poroelasticity model, the assumptions are isotropic linear elastic medium, quasi-static and isothermal conditions, and small deformation. The linear poroelasticity model is discretized in space using conforming Galerkin finite element method (CG) with piecewise linear base functions for displacement. The coupled compositional flow and linear poroelasticity model is a set of equations; pressure of the reference phase, total number of moles for each component, and solid phase displacement vector.

A comprehensive composition consistent three phase relative permeability model is developed and implemented. The effect of hysteresis is also modeled. 3D corner point grid geometry is implemented. In order to model the mobility control for CO_2 injection to improve the sweep efficiency, several foam models are implemented and validated against laboratory corefloods.

Both bottom-hole pressure and flow-rate well conditions are options available.

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2 INPUT AND OUTPUT FILES

DOECO2 requires one input data file for non-restart runs. For restart runs, a restart file is required in addition to the input data file used for the previous run.

Unit	File Name	Purpose
1	INPUT.DAT	Input data file (input)
2	TEST.ECH	Echo-print of input data file
3	TEST.RES	Restart file (input)
4	TEST.STO	Stored data for restart run
7	TEST.PRF	Profiles for 1-D runs
8	TEST.TBL	Detailed output in tabular form
9	TEST.HIS	Well history file
10	TEST.CON	Profiles for 2-D and 3-D runs
13	TEST.ERR	Error counters
16	TEST.CPU	Simulator CPU information
17	TEST.MES	Flash calculation information
20	TEST.DET	Δt computed based on time-step control parameters
21	TEST.IFO	Dilute surfactant results
22	TEST.SOL	Foam results
30	TEST.ASP	Asphaltene results
40	TEST.TRP	Trapping parameters
50	TEST.DBG	Debug file
51	TEST.RPM	Relative permeability and hysteresis parameters

The user-defined parameters in the following table are used by the simulator in order to define the array sizes. All the parameter values must be equal to (or greater than) the size of the grid dimensions and component number specified in the input file.

Parameter	**Definition**
NBM	Maximum number of grid blocks (needed for unstructured grids)
NXM	Maximum number of grid blocks in X-direction
NYM	Maximum number of grid blocks in Y-direction
NZM	Maximum number of grid blocks in Z-direction
NPM	Maximum number of phases (3 or 4)
NCM	Maximum number of components
NWM	Maximum number of wells
NWBCM	Maximum number of well blocks completed (=NXM+NYM+NZM)
NBWM	Maximum bandwidth of the pressure matrix (set to 7 if Thomas method or iterative solvers are used—set to actual bandwidth or 7, whichever is greater, if Gaussian elimination is used) Note: The bandwidth for the Gaussian elimination method is: $2 \times NY + 1$ if IGEOM=21 (2D X-Y) or 22 (2D Y-Z) $2 \times NZ + 1$ if IGEOM=23 (2D X-Z) $2 \times NY \times NZ + 1$ if IGEOM=31 (3D)
NPRM	Maximum number of time-steps in printing results to TABLE data file (.TAB)
NPFM	Maximum number of time-steps in printing results to PROFILE data file (.PRF)
NCTM	Maximum number of time-steps in printing results to CONTOUR data file (.CON)
NHSM	Maximum number of time-steps in printing results to HISTORY data file (.HIS)
NCMT	Maximum number of tracers

3 INPUT DATA DESCRIPTION

The main input file (INPUT.DAT) consists of comment lines and data lines. All comment lines are ignored by the simulator. The first twenty-three lines of the input file are reserved for comment lines used to briefly describe the input file. Each data line is preceded by three comment lines; unless otherwise noted, it is read in free format. Each input section is preceded by seven comment lines.

The following is a list of variables. The variable names appear in all-caps on a single line in the order they are read by the program. Every list of variables is followed by a description of each variable and corresponding units or possible values if applicable. An index of input parameters is provided in Appendix G. Input variables are read in the following order:

- Hydrocarbon data and flash calculations Output options
- Reservoir data
- Initial conditions
- Initial concentrations
- Poroelasticity model data
- Recurrent well condition data

3.1 Hydrocarbon Data and Flash Calculation Options

The first input section consists of the title of the problem, hydrocarbon data, and flash calculation options. Three comment lines precede each data line, starting with 3.1.1.

3.1.0 Comment Lines

The first 23 lines of the input file are reserved for comment lines used to briefly describe the input file and its application. The next 7 comment lines are to be used for describing the hydrocarbon system. Each comment line can be up to 70 characters long.

3.1.0a NXM, NYM, NZM, NPM, NCM, NCMT, NWM, IXYZ, IMESH, POSTPROCESSOR

NXM- Maximum number of grid blocks in x direction
NYM- Maximum number of grid blocks in y direction
NZM- Maximum number of grid blocks in z direction
NPM- Maximum number of phases
NCM- Maximum number of components
NCMT- Maximum number of tracers
NWM- Maximum number of wells (either injection or production)

Note: The user should verify the array sizes here to be large enough to accommodate the block configurations and the number of components specified in the input file before running the simulator

IXYZ- The index for grid block numbering

Possible Values:

0: The Y-direction is the fastest moving grid, then Z-direction, and X-direction is the slowest.
1: The X-direction is the fastest moving grid, then Y-direction, and Z-direction is the slowest.

IMESH- The index for grid block option for Cartesian, Corner point, or unstructured

0: Cartesian
1: Corner point or unstructured grid

Note: When corner point option is selected, the user needs to specify the mesh format in a separate file called MESH. The MESH file contains:

IGRIDTYPE:

0: It reads ZCORN and COORD
1: It reads XCORN, YCORN, and ZCORN

NX NY NZ: Number of grid blocks in x, y, and z direction.

If IGRIGTYPE=1, XCORN, YCORN, and ZCORN need to be specified.

XAC
YAC
ZAC

Appendix G illustrates two examples.

POSTPROCESSOR-

Possible Values:

0: no postprocessor
1: KRAKEN
2: S3GRAF

3.1.0b IGEOM, NBM (This line is read only if IMESH = 1)

IGEOM - Reservoir geometry flag.

Possible Values:

20: 2-D in X-Y areal (Unstructured)
30: 3-D (Unstructured)
50: Corner Point grid

NBM- Maximum number of grid blocks

3.1.0c NBWM, NPRM, NPFM, NCTM, NHSM, NPRPERMM NS3OUT

NBWM- Maximum bandwidth of the pressure matrix (set 7 if the Thomas method or iterative solvers are used – set to actual bandwidth or 7, whichever is greater, if Gaussian alimentation is used)
NPRM- Maximum number of time-steps in printing results to TABLE data file (.TAB)
NPFM- Maximum number of time-steps in printing results to PROFILE data file (.PRF)
NCTM- Maximum number of time-steps in printing results to CONTOUR data file (.CON)
NHSM- Maximum number of time-steps in printing results to HISTORY data file (.HIS)
NPRPERMM- Maximum number of relative permeability parameters printing to RPM file (.RPM)
NS3OUT-Maximum number of parameters printing to S3GRAF output

3.1.0d INQUA, INCON, INVEL, NOSWTM
INQUA- Maximum number of quality tables, Note: NQUA (number of quality tables) must be between 1 and INQUA
INCON- Maximum number of concentration columns, Note: NCON (number of concentration columns in tables) must be between 1 and INCON
INVEL- Maximum number of velocity entries, Note: NVEL (number of velocity entries) must be between 1 and INVEL
NOSWTM- Maximum number of table entries for the hydrocarbon dissolution table

3.1.1 HEADER
HEADER - Run title. The title must fit on one input line and can be up to 70 characters long.

3.1.2 NC
NC - Number of components.
Possible Values: 0 < NC < Maximum array dimensions declared in line 3.1.0a

3.1.3 NAME(K), for K=1, NC
NAME(K) - Name of component K.
Note: The name can consist of any combination of up to 8 alphanumeric characters. Each name must be on a separate line of the input file and must start at the second space (the first character is ignored and the next 8 are read by the program).

3.1.4 SLNTY, IAQUIF
SLNTY - Aquifer/Reservoir salinity
Units: ppm
IAQUIF - Flag indicating whether CO2 sequestration in aquifer option will be used or not.
Possible Values:
0 : Aquifer option will not be used

1 : Aquifer option will be used

Note: When aquifer option is selected, very little water as inactive water is assigned to phase 1, water is phase 2, and gas remains to be phase 3. CO_2 is selected as the first component, water as the second component, and hydrocarbon components are assigned to components 3 and above.

3.1.5 PC(K), TC(K), VC(K), WT(K), OM(K), PARACH(K), VSP(K), for K=1, NC

PC(K) - Critical pressure for component K

Units: psi

TC(K) - Critical temperature for component K.

Units: ˚R

VC(K) - Critical volume for component K (if IVISC=1) or viscosity of component K (if IVISC=2 or 3).

Units: ft^3/lb-mole (IVISC=1) or cp (IVISC=2 or 3)

Note: When aquifer option is selected, critical volume of water, VC(2), is replaced by a calculated value accounting for salinity.

WT(K) - Molecular weight for component K.

Units: lbm/lb-mole

OM(K) - Pitzer eccentric factor for component K.

PARACH(K) - Parachor for component K.

Units: $dynes^{1/4}\ cm^{11/4}$ / gm-mole

VSP(K) - Volume shift parameter for component K in Peng-Robinson equation of state.

Units: dimensionless

Note1: Volume shift parameters used in DOECO2 are dimensionless. But, few PVT packages report the values of volume shift as the required reduction in molar volume of each component (in ft^3/lb-mole). In such cases, these should be divided by the constant b (in EOS) of each component before they can be used by DOECO2.

Note2: When aquifer option is selected, volume shift parameter for water will be required. This correction for water density is applied directly to the molar density calculated by the EOS and has the units of lb-mole/ft^3.

3.1.6 PARAA(K), PARAB(K), for K=1, NC

PARAA(K) - Ω_A, Peng-Robinson and RKES constant for component K.

PARAB(K) - Ω_B, Peng-Robinson and RKES constant for component K.

Note: Generally, PARAA and PARAB are constants for Peng-Robinson EOS. PARAA=0.457236 and PARAB=0.0778.

3.1.7 DELTA(K,J), for J=1, K, and K=1, NC

DELTA(K,J) - Binary Interaction coefficients, C_{ij}.

Note: A lower triangular matrix will be read by DOECO2.

3.1.8 DIJ(K,J), for J=1, K, and K=1, NC

DIJ(K,J) - Binary Interaction coefficients, D_{ij}.

Note: A lower triangular matrix will be read by DOECO2. These values are used in

RKES only.

3.1.9 NP, IVISC, IVISC_COEF, ISINGL, ISOLU

NP - Number of phases.

Possible Values: 3 or 4

IVISC - Viscosity calculation flag.

Possible Values:

1 : Lohrenz, et al. correlation viscosity calculation is used

2 : Quarter-power mixing rule viscosity calculation is used

3 : Linear mixing rule viscosity calculation is used

IVISC _COEF- Flag for inputting coefficients in Lohrenz correlation.

Possible Values:

0: Using a default values

1: Using values defined by user (3.1.11)

ISINGL - Flash calculation option flag.

Possible Values:

0 : All single hydrocarbon phase grid blocks are tested

1 : Only single hydrocarbon phase grid blocks adjacent to grid blocks containing multiple phases are tested for the appearance of a second hydrocarbon phase

Note: Setting this flag to 1 is useful for simulations involving large numbers of grid blocks that contain a single hydrocarbon phase.

ISOLU - Hydrocarbon solubility in aqueous phase flag.

Possible Values:

0 : Hydrocarbon solubility in the aqueous phase is ignored.

1 : Hydrocarbon solubility in the aqueous phase is estimated using Henry's Law.

Note: The scalar flash routine must be used (set IVECFL=0) when estimating hydrocarbon solubility (ISOLU=1).

3.1.10. COEF1, COEF2, COEF3, COEF4, COEF5 (If IVISC_COEF=1)

If (IVISC_COEF=1) COEF1, COEF2, COEF3, COEF4 and COEF5 are constants and were defined in the program otherwise, they can use as the matching parameters for the viscosity versus pressure laboratory data.

Default Values:

COEF1= 0.1023

COEF2= 0.023364

COEF3= 0.058533

COEF4= -0.040758

COEF5= 0.0093324

3.1.11 IEOS, IPEM, ISTAM, IEST, IVSP, KI

IEOS - Equation-of-state selection flag.

Possible Values:

1 : Peng-Robinson equation-of-state (PRES)

3 : Redlich-Kwong equation-of-state (RKES)

IPEM - Flash calculation selection flag.

Possible Values:

0 : Accelerated successive substitution (ACSS)
1 : ACSS plus minimization of Gibbs free energy

ISTAM - Method of stability analysis selection flag.
Possible Values:
-1 : Stationary point with successive substitution (SS) and Newton-Raphson iteration
0 : Stationary point with SS
1 : Minimization

IEST - Method of initial estimation for flash calculation selection flag.
Possible Values:
0 : Results of stability analysis
1 : Previous results

IVSP - Volume shift parameter selection flag for Peng-Robinson equation of state.
Possible Values:
0 : Volume shift parameter is not used
1 : Volume shift parameter is used

Note1: If PR EOS is not used, the volume shift option will not be used and IVSP is set to zero by the simulator.

Note2: When aquifer option is selected, IVSP will be set to zero by the simulator, but volume shift parameter for water will be used to correct molar density of water from PR EOS. Note that this is the only case where the volume shift parameter has the units of molar density (lb-mole/ft^3).

KI - Flag indicating whether the Ki-value option is used.
Possible Values:
0 : Ki-value option is not used (EOS method)
1 : Ki-value option is used
2 : Alternative flash option is used

Note: Based on our experience, IPEM = 1, ISTAM = -1, and IEST = 1 is the preferred combination to be used when running DOECO2.

3.1.12 TB(K), for K=1, NC

TB(K) - True boiling point of K^{th} component.
Units: ˚R

3.1.13 TOLFLA, TOLFLM, TOLPD, TOLSAM, TOLSAS, TOLSUM

TOLFLA - Tolerance of ACSS flash calculation.
Example Value: 10^{-10}

TOLFLM - Tolerance of Gibbs free energy minimization flash calculation.
Example Value: 10^{-10}

TOLPD - Tolerance of L-V calculation.
Example Value: 10^{-10}

TOLSAM - Tolerance of minimization method for stability analysis.
Example Value: 10^{-8}

TOLSAS - Tolerance of stationary point stability analysis.
Example Value: 10^{-8}

TOLSUM - A small number for testing $\Sigma Y_i > 1$ in stationary analysis.
Example Value: 10^{-5}

3.1.14 MAXFLA, MAXFLM, MAXPD, MAXSAM, MAXSAS

MAXFLA - Maximum number of iterations for ACSS flash calculation.
Example Value: 50

MAXFLM - Maximum number of iterations for Gibbs free energy minimization flash calculation.
Example Value: 50

MAXPD - Maximum number of iterations for L-V calculation.
Example Value: 50

MAXSAM - This variable is currently not used in DOECO2. It is anticipated that this value will be used in a future version of the program.

MAXSAS - Maximum number of iterations for stationary point stability analysis.
Example Value: 50

3.1.15 IVECFL, TOLVFL, MAXVFL

IVECFL - Flag indicating type of flash routine to be used.
Possible Values:
0 : Scalar flash routine used
1 : Two-phase vector flash routine used
Note: The scalar flash routine must be used (set IVECFL=0) when estimating hydrocarbon solubility (ISOLU=1).

TOLVFL - Tolerance for two-phase vector flash calculation.
Example Value: 10^{-8}

MAXVFL - Maximum number of iterations for two-phase vector flash calculations.
Recommended Value: 15

3.1.16 SWIPCC, SWIPSA

SWIPCC - The criterion for switching from ACSS method to Gibbs free energy minimization in flash calculation.
Example Value: 10^{-2}
Note: This value is only used when IPEM=1.

SWIPSA - The criterion for switching from SS method to Newton-Raphson method in the stationary point stability analysis.
Example Value: 1.0
Note: This value is only used when ISTAM = -1.

3.1.17 IOIL, ITRK, DMSLIM

IOIL - Flag indicating if an oil phase exists initially.
Possible Values:
0 : No oil phase initially
1 : Oil phase exists initially

ITRK - Component number used in phase tracking.
Possible Values: 1 to NC

DMSLIM - Number used to distinguish the gas and second liquid phase.
Units: lbm/ft^3
Example Value: 25
Note: If a phase density is smaller than DMSLIM, phase is assigned to be a gas.

3.1.18 IFLAGT

IFLAGT - Flag indicating whether tracer option will be used or not.

Possible Values:

0 : Tracer option will not be used

1 : Tracer option will be used

Note: If polymer or foam option is desired, tracer option should be used since these applications are simulated as an extension of tracer option.

<u>If Tracer Option is not used (IFLAGT=0) skip to 3.2.0</u>

3.1.19 NCTR (This line is read only if IFLAGT=1)

NCTR - Number of tracers used.

Note: NCTR must be between 1 and NCMT (the maximum number of tracers parameter in the source code).

3.1.20 NAMET(K), for K=1, NCTR (This line is read only if IFLAGT=1)

NAMET(K) - Name of K^{th} tracer.

Note: The name can consist of any combination of up to 8 alphanumeric characters. Each name must be on a separate line of the input file and must start at the second space (the first character is ignored and the next 8 are read by the program).

3.1.21 ITYPET(K), IUNIT(K), IPGT(K), RKT(K), BI(K), RLAMDA(K), ICAPFL(K), for K=1, NCTR (This line is read only if IFLAGT=1)

ITYPET(K) - Flag indicating tracer type for K^{th} tracer.

Possible Values:

1 : Water tracer - a tracer that is only soluble in aqueous phase

2 : Oil tracer - a tracer that is only soluble in oleic phase

3 : Gas tracer - a tracer that is only soluble in gas phase

IUNIT(K) - Flag indicating concentration units for K^{th} tracer.

Possible Values:

1 : Concentration units are in ppm

2 : Concentration units are in dpm/liter

3 : Concentration units are in meq/ml

IPGT(K) - Flag indicating pressure-dependent gas tracer partitioning for K^{th} tracer.

Possible Values:

0 : The partition coefficient of gas tracer is constant and independent of pressure

1 : The partitioning of gas tracer depends on pressure and follows Henry's law

RKT(K) - Tracer partition coefficient (if IPGT(K)=0) or Henry's constant (if IPGT(K)=1) for K^{th} tracer.

Possible Values: must be greater than or equal to 0.0

Units: fraction

Note: Tracer partitioning is dependent on the combination of the ITYPET(K), IPGT(K), and RKT(K) variables. For a tracer that partitions between the water and oil phases, set ITYPET(K) to 1 and RKT(K) to be greater than

0. The partition coefficient in this case is defined as the concentration of tracer in the oil phase divided by the concentration of tracer in the aqueous phase.

$$K_T = \frac{C_{T,o}}{C_{T,w}}$$

For a tracer that partitions between the gas and oil phases, set ITYPET(K) to 3 and RKT(K) to be greater than 0. Then, the partition coefficient is defined as the concentration of tracer in the oil phase divided by the concentration of tracer in the gas phase.

$$K_T = \frac{C_{T,o}}{C_{T,g}}$$

BI(K) - Intercept of the plot of equilibrium ratio versus 1/P, where P is the pressure. The slope of this plot gives the Henry's constant.
Units: mole fraction

RLAMDA(K) - Radioactive decay coefficient for K^{th} tracer. A value of 0.0 indicates a non-radioactive tracer.
Units: 1/day

Note: $C = C_0 e^{-\lambda_k (t-t_0)}$

ICAPFL(K) - Flag indicating if the capacitance model is used or not for K^{th} tracer.
Possible Values:
0 : Capacitance model is not used
1 : Capacitance model is used

3.1.22 DIFUNT(J,K), for K=1, NCTR, for J=1, NP (This line is read only if IFLAGT=1)

DIFUNT(J,K) - Molecular diffusion coefficient for K^{th} tracer in J^{th} phase.
Units: ft^2/day

3.1.23 FFL(J), FFH(J), CM(J,K), for K=1, NCTR, for J=1, NP (This line is read only if IFLAGT=1)

FFL(J) - Value of flowing fraction for J^{th} phase when fraction flow = 0.0.

FFH(J) - Value of flowing fraction for J^{th} phase when fraction flow = 1.0.

CM(J,K) - Mass transfer coefficient for K^{th} tracer in J^{th} phase.

3.1.24 NMONCT, NDIVCT, BETASE, CSE1 (This line is read only if IFLAGT=1)

NMONCT - Tracer number for monovalent cation.

NDIVCT - Tracer number for divalent cation.

BETASE - Parameter, β_{SE}, for calculating the effective divalent salinity.
Units: dimensionless

CSE1 - Minimum salinity used in the adsorption calculation.
Units: same as monovalent and divalent cation concentrations
Note: The salinity, C_{SE}, for tracer adsorption is defined as:

$$C_{SE} = C_{NMONCTj} + \beta_{SE} C_{NDIVCTj}$$

where j is the phase with largest phase concentration. If $C_{SE} < CSE1$, then set $C_{SE} = CSE1$. The concentration units specified for monovalent and divalent cations should be the same.

3.1.25 A1ADT(K), A2ADT(K), BADT(K), IADIRV(K), for K=1, NCTR (This line is read only if IFLAGT=1)

A1ADT(K) - Adsorption parameter, A_{1i}, for K^{th} tracer.

Units: dimensionless

A2ADT(K) - Adsorption parameter, A_{2i}, for K^{th} tracer.

Units: 1/(unit of salinity)

Note: $A_{2i}C_{SE}$ is dimensionless

BADT(K) - Adsorption parameter, B_i, for K^{th} tracer

Unites: 1/(unit of concentration for K^{th} tracer)

Note: B_iC_{ij} is dimensionless

IADIRV(K) - Flag indicating whether or not the adsorption is reversible to salinity and concentration.

Possible Values:

0 : Adsorption is reversible to both salinity and concentration

1 : Adsorption is not reversible to salinity or concentration

2 : Adsorption is reversible to salinity but irreversible to concentration

Note: $$\overline{C}_i = \frac{\left[A_{1i} + A_{2i}C_{SE}\right]C_{ij}}{1 + B_iC_{ij}}$$

where j is the phase with the largest phase concentration.

3.1.26 IFPLYT (This line is read only if IFLAGT=1)

IFPLYT - Flag indicating whether the polymer option is used or not.

Possible Values:

0 : Polymer option is not used

1 : Polymer option is used

Note: If polymer option is desired, tracer option should be used since this application is simulated as an extension of the tracer option.

<u>If Polymer Option is not used (IFPLYT=0) skip to 3.1.31</u>

3.1.27 NPLYT (This line is read only if IFPLYT=1)

NPLYT - Tracer number for polymer.

3.1.28 AP1, AP2, AP3, SSLOPE (This line is read only if IFPLYT=1)

AP1 - Parameter for calculating polymer solution viscosity at zero shear rates as a function of polymer and electrolyte concentrations.

Units: $$\frac{1}{(\text{unit of polymer concentration})^2 \times (\text{unit of salinity})^{S_p}}$$

Note: $A_{P1}C_{P1}C_{SE}^{S_p}$ is dimensionless

AP2 - Parameter for calculating polymer solution viscosity at zero shear rates as a function of polymer and electrolyte concentrations.

Units: $\dfrac{1}{(\text{unit of polymer concentration})^2 \times (\text{unit of salinity})^{S_P}}$

Note: $A_{P2}C_{p1}^2 C_{SE}^{S_P}$ is dimensionless

AP3 - Parameter for calculating polymer solution viscosity at zero shear rates as a function of polymer and electrolyte concentrations.

Units: $\dfrac{1}{(\text{unit of polymer concentration})^3 \times (\text{unit of salinity})^{S_P}}$

Note: $A_{P3}C_{p1}^3 C_{SE}^{S_P}$ is dimensionless

SSLOPE - Exponent, Sp, for calculating polymer solution viscosity at zero shear rates as a function of polymer and electrolyte concentration.

Units: dimensionless

Note: The polymer solution viscosity at zero shear rate is modeled by:

$$\mu_0 = \mu_w \left[1 + \left(A_{p1}C_{p1} + A_{p2}C_{p1}^2 + A_{p3}C_{p1}^3 \right) C_{SE}^{S_P} \right]$$

3.1.29 GAMMAC, GAMHF, POWN (This line is read only if IFPLYT=1)

GAMMAC - Coefficient, γ_c, in shear rate equation

Units: $\dfrac{\text{ft (darcy)}^{1/2}}{\text{ft sec}}$

GAMHF - Shear rate, $\gamma_{1/2}$, at which polymer viscosity is one half polymer viscosity at zero shear rate.

Units: sec^{-1}

POWN - Exponent, P_α, for calculating shear rate dependence of polymer viscosity.

Units: dimensionless

Note: The shear-rate dependence of polymer viscosity is modeled by Meter's equation:

$$\mu_p = \mu_\infty + \frac{\mu_0 - \mu_\infty}{1 + \left(\dfrac{\gamma}{\gamma_{1/2}} \right)^{P_\alpha - 1}}$$

where $\gamma = \dfrac{\gamma_c \left| \bar{U}_1 \right|}{\sqrt{k k_{r1} \phi S_1}}$ and $\bar{k} = \left[\dfrac{1}{k_x} \left(\dfrac{u_{x1}}{|u_1|} \right)^2 + \dfrac{1}{k_y} \left(\dfrac{u_{y1}}{|u_1|} \right)^2 + \dfrac{1}{k_z} \left(\dfrac{u_{z1}}{|u_1|} \right)^2 \right]^{-1}$

3.1.30 EPRPLY, BRK, CRK (This line is read only if IFPLYT=1)

ERPLY - Effective porosity factor for polymer. It is the ratio of apparent porosity for polymer to actual reservoir porosity.

BRK - Parameter, b_{rk}, for calculating permeability reduction factor, R_K.

Units: $(\text{unit of polymer concentration})^{-1}$

Note: $b_{rk}C_{p1}$ is dimensionless

CRK - Parameter, C_{rk}, for calculating the permeability reduction factor, R_K.

Units: $\dfrac{(\text{darcy})^{1/2}}{(\text{unit of polymer concentration})^{1/3}}$

Note: The permeability reduction factor is modeled by:

$$R_k = 1 + \frac{(R_{K\max} - 1)\, b_{rk} C_{p1}}{1 + b_{rk} C_{p1}}$$

where $$R_{K\max} = \left[1 - \frac{C_{rk}(A_{p1} C_{SE}^{S_P})^{1/3}}{\left(\dfrac{\sqrt{k_x k_y}}{\phi} \right)^{1/2}} \right]^{-4}$$

The effect of permeability reduction is to reduce the mobility of the polymer rich phase (water phase). It is modeled in the program by multiplying the water phase viscosity by R_K.

3.1.31 IFOSW (This line is read only if IFLAGT=1)

IFOSW - Flag indicating whether the dilute surfactant option will be used or not.

Possible Values:

0 : Dilute surfactant option will not be used

1 : Dilute surfactant option will be used

<u>If Dilute Surfactant Option is not used (IFOSW=0) skip to 3.1.38</u>

3.1.32 NSRFT (This line is read only if IFSOW=1)

NSRFT - Tracer number for surfactant.

3.1.33 NOSWT (This line is read only if IFSOW=1)

NOSWT - Number of inputs for the hydrocarbon dissolution table.

Note: NOSWT must be between 1 and NOSWTM.

3.1.34 (SRFT(IT), (ROSWT(IT,K), for K=1, NC), for IT=1, NOSWT) (This line is read only if NOSWT>0)

SRFT(IT) - Surfactant concentration in the aqueous phase for the hydrocarbon dissolution table.

Units: $\dfrac{\text{lb-mass of surfactant}}{\text{lb-mass of water-hydrocarbon solution}}$

ROSWT(IT,K) - Partition coefficient for K^{th} component

Units: dimensionless

Note: When the surfactant concentration is smaller than SRFT(1), ROSWT(1,K) will be used. When the surfactant concentration is larger than SRFT(NOSWT), ROSWT(NOSWT,K) will be used. Otherwise, linear interpolation from the table values will be used.

3.1.35 RATEM(K), for K=1, NC (This line is read only if IFOSW=1)

RATEM(K) - Kinetic mass transfer coefficient.

Units: $\frac{\text{lb mol}}{\text{bulk vol.-day}}$

Note: Set RATEM(K)= 0 for equilibrium case.

3.1.36 IFT, G1, G2, G3, CHUH (This line is read only if IFOSW=1)

IFT - Flag indicating which interfacial tension is used.

Possible Values:

0 : Healy-Reed-Hirasaki's interfacial tension model is used

1 : Chun Huh's interfacial tension model is used

G1, G2, G3 - Interfacial tension parameters for Healy-Reed-Hirasaki's model.

Units: dimensionless

CHUH - Interfacial tension parameter for Chun Huh's model.

Units: dynes/cm

3.1.37 CS, PS, DENSS, SCMC (This line is read only if IFOSW=1) CS

- Surfactant compressibility.

Units: psi^{-1}

PS - Surfactant reference pressure.

Units: psi

DENSS - Surfactant mass density at reference pressure.

Units: $lb\text{-}mass/ft^3$

SCMC - Critical micelle concentration (minimum surfactant concentration for the formation of micelles).

Units: volume fraction

3.1.38 IFOAM (This line is read only if **IFLAGT=1**)

IFOAM - Flag indicating whether the foam option will be used or not.

Possible Values:

0 : Foam option will not be used

1 : Foam table lookup option will be used

2 : Pc* foam model will be used

3 : Population balance model (Local-Equilibrium Approximation)

Note: If foam option is desired, tracer option should be used since this application is simulated as an extension of tracer option.

If Foam Option is not used (IFOAM=0) skip to line 3.2.0

3.1.39 NFOAM (This line is read only if IFOAM=1)
NFOAM - Tracer number for foam.

If IFOAM=2 skip to line 3.1.45

If IFOAM =3 skip to line 3.1.47

3.1.40 CSLIM, SOLIM, SWLIM, SGLIM, VGLIM, RMOBMI (This line is read only if IFOAM=1)
CSLIM - Limiting surfactant concentration below which there is no foam.
Units: ppm
SOLIM - Limiting oil saturation above which there is no foam.
SWLIM - Limiting water saturation below which there is no foam.
SGLIM - Limiting gas saturation below which there is no foam.
VGLIM - Critical gas interstitial velocity below which there is no foam.
Units: ft/day
RMOBMI - Minimum nonzero acceptable foam relative mobility.
Units: 1/cp
Notes: Set VGLIM = -1 to turn off critical velocity option.
RMOBMI is 2-3 orders of magnitude less than pure gas mobility.

3.1.41 NQUA, NCON, NVEL (This line is read only if IFOAM=1)
NQUA - Number of quality tables.
NCON - Number of concentration columns in tables.
NVEL - Number of velocity entries.
Note1: NQUA must be between 1 and INQUA, NCON must be between 1 and INCON, and NVEL must be between 1 and INVEL (the maximum number of table entries defined in line 3.1.0d).
Note2: Each table is read in increasing order of quality. The size of table for each quality should be the same (that is, same number of concentration columns and same number of velocity rows).

Lines 3.1.42 Through 3.1.44 are Repeated for JQ=1, NQUA

3.1.42 TQUA(JQ) (This line is read only if IFOAM=1)
TQUA(JQ) – Value of foam quality for each table.
Units: %

3.1.43 TCON(KC,JQ), for KC=1,NCON (This line is read only if IFOAM=1)
TCON(KC,JQ) - Surfactant concentrations for each table
Units: ppm
Note: The TCON(KC) values should be input in increasing order of concentration.Concentration of the first table, TCON(1), should be equal to CSLIM and concentration of the last table, TCON(NCON) should be the injection surfactant concentration.

3.1.44 (TVEL(I,JQ), (TRES(I,KC,JQ), for KC=1, NCON), for I=1, NVEL) (This line is read

only if IFOAM=1)
TVEL(I,JQ) - Interstitial velocity.
Units: ft/day
TRES(I,KC,JQ) - Resistance factor.
Units: dimensionless
Note: The TVEL(I,JQ) values should be entered in increasing order of velocity.

3.1.45 CSTAR, SOSTAR, RFMAX, VELGR, SHRTN, EPXLO (This line is read only if IFOAM=2)
CSTAR - Critical surfactant concentration below which foam is not generated.
Units: volume fraction
SOSTAR - Critical oil saturation above which foam is not generated.
Units: dimensionless
RFMAX- Maximum foam "R" parameter.
Units: dimensionless
VELGR - Reference gas velocity.
Units: ft/day
SHRTN - Gas shear thinning exponent.
Units: dimensionless
EPXLO - Water saturation tolerance parameter in foam model.
Units: dimensionless

3.1.46 SWSTAR (This line is read only if IFOAM=2)
SWSTAR – Constant Sw*
Units: dimensionless

3.1.47 AKFP0, AKFM0, AKFM20, ANFS, PCSM, CF3SR, ALPHF, XTRP, SOLIM (This line is read only if IFOAM=3)
AKFP0 - Rate coefficient for foam generation.
Units: $day^{1/3}ft^{-13/3}$
AKFM0 - Rate coefficient for foam coalescence.
Units: ft^{-1}
AKFM20- Number of oil-gas contact sites per volume of gas.
Units: ft^{-1}
ANFS - The upper limit for the concentration of foam bubble.
Units: ft^{-3}
PCSM - The limiting value of capillary pressure for foam coalescence.
Units: Psi
CF3SR - Reference surfactant concentration for strong net foam generation.
Units: ppm
ALPHF - The constant of proportionality for foam viscosity equation that varies with surfactant formulation and permeability.
Units: $cp\ day^{-1/3}ft^{10/3}$
XTRP - The fraction of trapped foam.
Units: dimensionless
SOLIM - Limiting oil saturation above which there is no foam.
Units: dimensionless

3.1.48 IFO3LE, BETAF (This line is read only if IFOAM=3)

IFO3LE - The flag to use LEM or LEA options.

Units: dimensionless

LEM : Local-Equilibrium Model.

LEA : Local-Equilibrium Approximation (Improved LEM by considering small fraction of the accumulation term.)

Possible Values:

1 : LEM option is used

2 : LEA option is used

BETAF - The fraction constant that determines the magnitude of the damping effect introduced by the accumulation term.

Units: dimensionless

3.2 Output Options

The second input section consists of output options.

3.2.0 Comment Lines

There are 7 comment lines, which are used for describing the output options. Each comment line can be up to 70 characters long.

3.2.1 NHSSKIP, NSTSKIP, IPV

NHSSKIP - Frequency of well history recording parameter.

Note: The well history will be recorded every NHSSKIPth time step in the output file TEST.HIS.

NSTSKIP - Frequency of restart data and well history printing parameter.

Note: The restart data and well history will be written to files STORE (TEST.STO) and HISTORY (TEST.HIS), respectively, every NSTSKIPth time step and at the last time step.

IPV - Flag indicating units used to specify output printing or final simulation times.

Possible Values:

0 : Time specified in days

1 : Time specified in pore volumes injected

3.2.2 CONC0(K), for K=1, NC

CONC0(K) – Reference concentration (C_i^o) for K^{th} component

Units: mole fraction

Note: The component effluent concentration (C_i) is normalized as C_i / C_i^o.

3.2.3 NPR

NPR - Number of times results will be written to the TABLE (TEST.TAB) file.

Note: NPR must be less than NPRM (the maximum number of table entries defined in line 3.1.0b).

3.2.4 TPR(I), MPRP(I), MPRSAT(I), MPRIND(I), MPROMFR(I), MPRPMFR(I), MPRPRO(I), MPRATES(I), for I=1, NPR (if NPR > 0)

TPR(I) - Time at which Ith printing interval to TABLE file will occur.

Units: days

Note: The TPR values must be listed in increasing order.

MPRP(I) - Flag indicating whether pressure values will be printed to TABLE file at Ith printing interval.

Possible Values:

0 : Do not print pressure values

1 : Print pressure values

MPRSAT(I) - Flag indicating whether saturation values will be printed to TABLE file at Ith printing interval.

Possible Values:

0 : Do not print saturation values

1 : Print saturation values

MPRIND(I) - Flag indicating whether phase index will be printed to TABLE file at Ith printing

interval.
Possible Values:
0 : Do not print saturation values
1 : Print saturation values

MPROMFR(I) - Flag indicating whether overall composition values will be printed to TABLE file at I^{th} printing interval.
Possible Values:
0 : Do not print overall composition values
1 : Print overall composition values

MPRPMFR(I) - Flag indicating whether phase composition values will be printed to TABLE file at I^{th} printing interval.
Possible Values:
0 : Do not print phase composition values
1 : Print phase composition values

MPRPRO(I) - Flag indicating whether phase property values (relative permeabilities, viscosities, mass densities, molar densities, interfacial tensions, and capillary pressures) will be printed to TABLE file at the I^{th} printing interval.
Possible Values:
0 : Do not print phase property values
1 : Print phase property values

MPRRATES(I) - Flag indicating whether well rate values will be printed to TABLE file at I^{th} printing interval.
Possible Values:
0 : Do not print well rate values
1 : Print well rate values

3.2.5 NPF

NPF - Number of times results will be written to PROFILE (TEST.PRF) file.
Note: NPF must be less than NPFM (the maximum number of table entries defined in line 3.1.0b).

3.2.6 TPF(I), MPFSAT(I), MPFOMFR(I), MPFPMFR(I), MPFPROP(I), for I=1, NPF (This line is read only if NPF>0)

TPF(I) - Time at which I^{th} printing interval to PROFILE file will occur.
Units: days
Note: The TPF values must be listed in increasing order.

MPFSAT(I) - Flag indicating whether saturation values will be printed to PROFILE file at I^{th} printing interval.
Possible Values:
0 : Do not print saturation values
1 : Print saturation values

MPFOMFR(I) - Flag indicating whether overall composition values will be printed to PROFILE file at I^{th} printing interval.
Possible Values:
0 : Do not print overall composition values
1 : Print overall composition values

MPFPMFR(I) - Flag indicating whether phase composition values will be printed to PROFILE file at I^{th} printing interval.

Possible Values:

0 : Do not print phase composition values

1 : Print phase composition values

MPRPROP(I) - Flag indicating whether phase property values (pressure, mass densities, molar densities, interfacial tensions, and capillary pressures) will be printed to PROFILE file at I^{th} printing interval.

Possible Values:

0 : Do not print phase property values

1 : Print phase property values

3.2.7 NCT

NCT - Number of times results will be written to CONTOUR (TEST.CON) file.

Note: NCT must be less than NCTM (the maximum number of table entries defined in line 3.1.0b).

3.2.8 TCT(I), MCTP(I), MCTSAT(I), MCTOMFR(I), MCTPMFR(I), MCTPRO(I), for I=1, NCT (This line will only be read if NCT>0)

TCT(I) - Time at which I^{th} printing interval to CONTOUR file will occur.

Units: days

Note: The TCT values must be listed in increasing order.

MCTP(I) - Flag indicating whether pressure values will be printed to CONTOUR file at I^{th} printing interval.

Possible Values:

0 : Do not print pressure values

1 : Print pressure values

MCTSAT(I) - Flag indicating whether saturation values will be printed to CONTOUR file at I^{th} printing interval.

Possible Values:

0 : Do not print saturation values

1 : Print saturation values

MCTOMFR(I) - Flag indicating whether overall composition values will be printed to CONTOUR file at I^{th} printing interval.

Possible Values:

0 : Do not print overall composition values

1 : Print overall composition values

MCTPMFR(I) - Flag indicating whether phase composition values will be printed to CONTOUR file at I^{th} printing interval.

Possible Values:

0 : Do not print phase composition values

1 : Print phase composition values

MCTPRO(I) - Flag indicating whether phase property values (relative permeabilities, viscosities, mass densities, molar densities, interfacial tensions, and capillary pressures) will be printed to CONTOUR file at the I^{th} printing interval.

Possible Values:

0 : Do not print phase property values

1 : Print phase property values

3.2.9 NPRPERM

NPRPERM-Number of relative permeability parameters written for specified grid(s) and phase(s) results will be written to RPM (TEST.RPM).

Note: NPRPERM must be less than NPRPERM (the maximum number of table entries defined in line 3.1.0b).

3.2.10 IPRPERMG, IPRPERMPH (This line will only be read if NPRPERM>0)

IPRPERMG - grid block for which relative permeability parameters are printed.

IPRPERMPH - the phase for which relative permeability parameters are printed.

3.3 Reservoir Data

This section of the input file consists of reservoir data. Three comment lines precede each data line, starting with 3.3.1

3.3.0 Comment Lines

There are 7 comment lines, to be used for describing the reservoir grid options. Each comment line can be up to 70 characters long.

3.3.1 IGEOM, INUG

IGEOM - Reservoir geometry flag.

Possible Values:

11 : 1-D in Y-direction
12 : 1-D in X-direction
13 : 1-D in Z-direction
21 : 2-D X-Y areal
22 : 2-D Y-Z cross sectional
23 : 2-D X-Z cross sectional
31 : 3-D
Note: The code reads these parameters but they are used when IMESH = 0.

INUG- Flag indicating whether variable-width cross-section option is active.

Possible Values:

0: Variable-width cross-section option is not active
1: Variable-width cross-section option is active

3.3.2 NX, NY, NZ

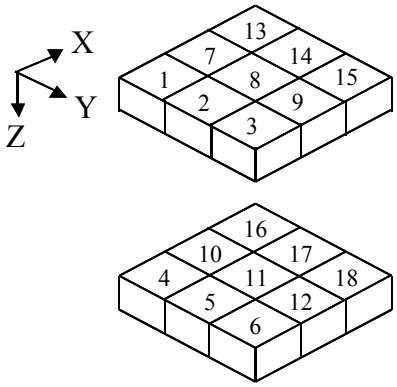
NX - Number of grid blocks in the X-direction.
NY - Number of grid blocks in the Y-direction.
NZ - Number of grid blocks in the Z-direction.

Note: NX, NY, and NZ must be smaller than NXM, NYM, and NZM respectively (the maximum number of grid blocks defined in line 3.1.0a). In DOECO2, the X- and Y-directions are used as areal coordinates and the Z- direction is defined in the vertical direction (depth, positive downward). For grid block numbering, there are two options corresponding to IXYZ flag which defined in line 3.1.0a.

IXYZ = 0

The Y-direction is the fastest moving grid, then Z-direction, and X-direction is the slowest.

Example of how the gridblocks in a 3 × 3 × 2 system would be numbered.



so the arrays are read and stored in the following order:

1,1,1 1,2,1 1,3,1
1,1,2 1,2,2 1,3,2
2,1,1 1,2,2 1,3,2
2,1,2 2,2,2 2,3,2
3,1,1 3,2,1 3,3,1
3,1,2 3,2,2 3,3,2

IXYZ = 1

The X-direction is the fastest moving grid, then Y-direction, and Z-direction is the slowest.

Example: If you had a 4×3×2 system (4 columns—NX=4, 3 rows—NY=3, and 2 layers—NZ=2), the values would be read in the following order:

1,1,1 2,1,1 3,1,1 4,1,1
1,2,1 2,2,1 3,2,1 4,2,1
1,3,1 2,3,1 3,3,1 4,3,1
1,1,2 2,1,2 3,1,2 4,1,2
1,2,2 2,2,2 3,2,2 4,2,2
1,3,2 2,3,2 3,3,2 4,3,2

3.3.3 NW, IWM

NW - Number of wells.

IWM - Flag indicating which equivalent well radius model is to be used.

Possible Values:

1 : Babu and Odeh model is to be used
2 : Peaceman model is to be used

3.3.4 RW(LW), for LW=1, NW

RW(LW) - Well bore radius or effective well bore radius of LW^{th} well.

Units: ft

3.3.5 LXW(LW), LYW(LW), IDIR(LW), LZWF(LW), LZWL(LW), for LW=1, NW

LXW(LW) - First index of the reservoir grid block containing the LW^{th} well.

Possible Values:

Between 1 and the number of grid blocks in the pertinent direction, inclusive

Note: If the LWth well is completed parallel to the X-axis, IW(I) is the Y-direction index; if the well is completed parallel to the Y- or Z-axis, IW(I) is the X-direction index. See example below.

LYW(LW) - Second index of the reservoir grid block containing the LWth well.

Possible Values: Between 1 and the number of grid blocks in the pertinent direction, inclusive

Note: If the LWth well is completed parallel to the X- or Y-axis, JW(I) is the Z-direction index; if the well is completed parallel to the Z-axis, JW(I) is the Y-direction index. See example below.

IDIR(LW) - Flag indicating the direction in which the LWth well is completed.

Possible Values:

1 : Well completed parallel to the X-axis
2 : Well completed parallel to the Y-axis
3 : Well completed parallel to the Z-axis
4 : Deviated well completion data

LZWF(LW) - Index of the first block in which the LWth well is completed.

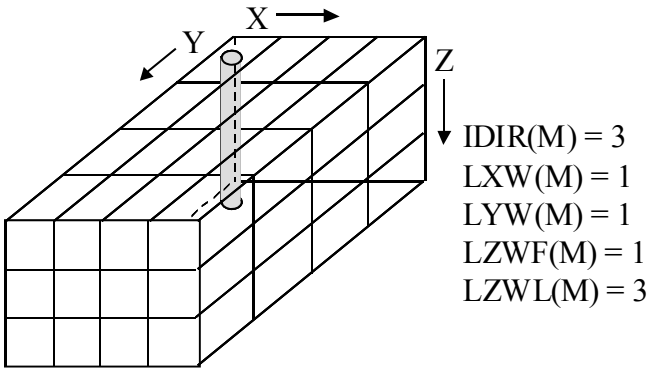
Possible Values: Between 1 and the number of grid blocks in the pertinent direction, inclusive.

LZWL(LW) - Index of the last block in which the LWth well is completed.

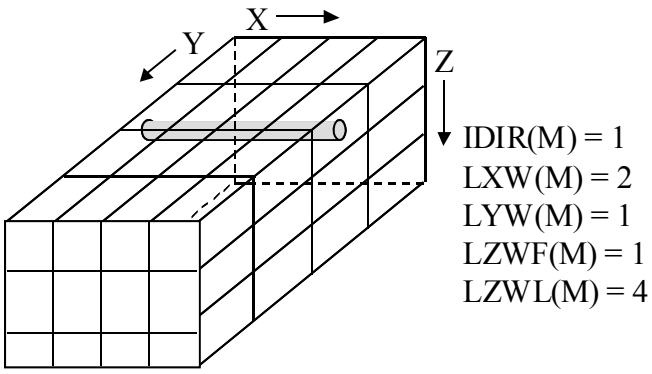
Possible Values: Between 1 and the number of grid blocks in the pertinent direction, inclusive.

Note: At this time, DOECO2 assumes the well is completed continuously between LZWF(I) and LZWL(I).

Example: For a vertical well (completed through all the layers) as illustrated in the 4 × 4 × 3 example below, note the values of IDIR(M), LXW(M), LYW(M), LZWF(M), and LZWL(M):



For a horizontal well (completed from the first to last grid block in the X direction and parallel to the X-axis) as illustrated in the 4 × 4 × 3 example below, note the values of IDIR(M), LXW(M), LYW(M), LZWF(M), and LZWL(M):



3.3.5a NWBC(LW) (This line is read only if IDIR(LW)=4)

NWBC(LW) - Number of well perforations for the LWth well.

3.3.5b IWC(LW, IWB), JWC(LW, IWB), KWC(LW, IWB), for IWB=1, NWBC(LW) (This Line is read only if IDIR(LW)=4)

IWC(LW, IWB) - The I-index (X-direction) of the IWBth perforation for the LWth well.

JWC(LW, IWB) - The J-index (Y-direction) of the IWBperforation for the LWth well.

KWC(LW, IWB) - The K-index (Z-direction) of the IWBth perforation for the LWth well.

Note: IWC(LW, IWB) must begin a separate line in the input file for each perforation.

PIMULT(LW, IWB) – The productivity index multiplier of the IWBth perforation for the LWth well.

3.3.6 MDX

MDX - Flag indicating whether the grid block sizes are constant in the X-direction.

Possible Values:

0 : The block sizes are constant in the X-direction

1 : The block sizes are variable in the X-direction

<u>If MDX=1 skip to 3.3.8</u>

3.3.7 DX (This line is read only if MDX=0)

DX - Gird block size in X-direction.

Units: ft

Note: If MDX=0 (the block sizes are constant in the X-direction), only one value is required by the program.

3.3.8 DX(LX), for LX=1, NX (This line is read only if MDX=1)

DX(LX) - Gird block size in X-direction.
Units: ft
Note: If MDX=1 (the block sizes are variable in the X-direction), NX values are required by the program.

3.3.9 MDY

MDY - Flag indicating whether the grid block sizes are constant in the Y-direction.
Possible Values:
0 : The block sizes are constant in the Y-direction
1 : The block sizes are variable in the Y-direction
Note: MDY must be set equal to 1 if using the variable-width cross-section option (INUG=1).

If MDY=1 skip to 3.3.11

3.3.10 DY (This line is read only if MDY=0)

DY - Gird block size in Y-direction.
Units: ft
Note: If MDY=0 (the block sizes are constant in the Y-direction), only one value is required by the program.

3.3.11 DY(LY), for LY=1, NY or NX (This line is read only if MDY=1)

DY(LY) - Gird block size in Y-direction.
Units: ft
Note: If MDY=1 (the block sizes are variable in the Y-direction) **and** INUG ≠ 1 (the variable-width cross-section option is not active), NY values are required by the program because the size of each grid block in the Y-direction must be specified.
If MDY=1 (the block sizes are variable in the Y-direction) **and** INUG=1 (the variable-width cross-section option is not active), NX values are required because the grid block size in the Y-direction at each X-node must be specified even though NY=1 (the grid block size in the Y-direction is constant for the NZ blocks at each given X location in the grid).

3.3.12 MDZ

MDZ - Flag indicating whether the grid block sizes are constant in the Z-direction.
Possible Values:
0 : The block sizes are constant in the Z-direction
1 : The block sizes are variable in the Z-direction

If MDZ=1 skip to 3.3.14

3.3.13 DZ (This line is read only if MDZ=0)

DZ- Gird block size in Y-direction.
Units: ft

Note: If MDZ=0 (the block sizes are constant in the Z-direction), only one value is required by the program.

3.3.14 DZ(LZ), for LZ=1, NZ (This line is read only if MDZ=1)
DZ(LZ) - Gird block size in Z-direction.

Units : ft

Note: If MDZ=1 (the block sizes are variable in the Z-direction), NZ values are required by the program.

3.3.15 MD
MD - Flag indicating whether the formation depth is constant.
Possible Values:
0 : Single value for depth of the middle of top layer is specified
1 : Middle depth of all grid blocks are specified
2 : Middle depth of the first grid block and the reservoir dip angles are specified
3 : Middle depth of grid blocks on top layer are specified
4: Middle depth of all grid blocks are read from DEPTH input file
5: Middle depth of grid blocks on top layer are read from DEPTH input file
Note: Depth is specified at the middle of a grid block and not the top.

If MD=1 skip to 3.3.17; if MD=2 or MD=4, skip to 3.3.18; if MD=3 or MD=5, skip to 3.3.19

3.3.16 D (This line is read only if MD=0)
D - Formation depth of middle of any grid on the top layer.
Units: ft
Note: If MD=0, D is the only input value used by the program.

3.3.17 D (I), for I=1, NB where NB=NX × NY × NZ (This line is read only if MD=1 or MD=4) D(I) - Formation depth of middle of the I^{th} grid block, for all blocks.
Units: ft
Note: If MD=1, NB values for D(I) are required by the program.

3.3.18 D, THETAX, THETAY (This line is read only if MD=2)
D - Formation depth of middle of the first grid block
Units: ft
THETAX - Reservoir dip angle in X-direction, positive downward.
Units: degrees
THETAY - Reservoir dip angle in Y-direction, positive downward.
Units: degrees

3.3.19 D(LX,LY,1), for LX=1, NX, and LY=1, NY (This line is read only if MD=3 or MD=5)
D(LX,LY,1) - Formation depth of middle of grid blocks on the top layer (Z=1).
Units: ft
Note: If MD=3 or MD=5, NX × NY values are required by the program.

3.3.20 MPOR, MNTG, MTRANZ, MMOD, IACTNUM

MPOR - Flag indicating whether the porosity is homogeneous or heterogeneous.

Possible Values:

0 : Porosity is homogeneous (constant for whole reservoir)

1 : Porosity is heterogeneous

2 : Porosity varies in the Z-direction (constant porosity for each layer)

3: Porosity values for each gridblock are read from POR input file

MNTG - Flag indicating whether net-to-gross values are input to modify gridblock pore volumes.

Possible Values:

0 - Net-to-gross values are not input

1 - Net-to-gross values are read from MNTG input file

MTRANZ - Flag indicating whether the transmissibilities are modified or not.

Possible Values:

0 - No transmissibility modifier

1-Use transmissibility modifier (file names; MULTX, MULTY, and MULTZ)

MMOD - Flag indicating whether the reservoir properties are modified or not.

Possible Values:

0 - No property is modified

1 - Allow for property modification

IACTNUM - Flag indicating whether active/inactive block index values are input or not.

Possible Values:

0 - Active/inactive block index are not input

1 - Active/inactive block index are read from file ACTNUM (1: active block, 0: inactive block)

<u>If MPOR=1 or MPOR =3 skip to 3.3.22; if MPOR=2, skip to 3.3.23</u>

3.3.21 PORSTD (This line is read only if MPOR=0)

PORSTD – Constant porosity for all grid blocks at formation pressure PF.

Units: fraction

Note: If MPOR=0 (the porosity is homogeneous), only one value is required by the program.

3.3.22 PORSTD(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if MPOR=1)

PORSTD(I) – NB Values of porosities of every grid blocks at formation pressure PF.

Units: fraction

Note: If MPOR=1 (the porosity is heterogeneous), NB values for PORSTD(I) are required by the program.

Note: If MPOR=3, Porosity values for each gridblock are read from POR input file

3.3.23 PORSTD (LZ), LZ = 1, NZ (This line is read only if MPOR=2)

PORSTD (LZ) – NZ Values of porosities of every layer at formation pressure PF.

Units: fraction

Note: If MPOR=2 (values vary in the Z-direction), NZ values are required by the program.

3.3.24 MPERMX

MPERMX - Flag indicating whether the absolute permeabilities in the X-direction are homogeneous or heterogeneous.

Possible Values:

0 : Permeabilities in the X-direction are homogeneous

1 : Permeabilities in the X-direction are heterogeneous

2 : Permeabilities in the X-direction varies in the Z-direction

3 : X direction permeability values for each gridblock are read from PERMX input file

If MPERMX=1 or MPERMX =3 skip to 3.3.26; if MPERMX=2, skip to 3.3.27

3.3.25 PERMX (This line is read only if MPERMX=0)

PERMX – Constant absolute permeabilities of all grid blocks in the X-direction.

Units: mD

Note: If MPERMX=0 (the absolute permeability in the X-direction is homogeneous), only one value is required by the program.

3.3.26 PERMX(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if MPERMX=1)

PERMX(I) – NB Values of absolute permeabilities of every grid blocks in the X-direction.

Units: mD

Note: If MPERMX = 1 (the absolute permeability in the X-direction is heterogeneous), NB values for are required by the program.

Note: If MPERMX ¥ =3, X direction permeability values for each gridblock are read from PERMX input file

3.3.27 PERMX(LZ), LZ = 1, NZ (This line is read only if MPERMX=2)

PERMX(LZ) – NZ Values of absolute permeabilities of every layer in the X-direction.

Units: fraction

Note: If MPERMX =2 (values vary in the Z-direction), NZ values are required by the program.

3.3.28 MPERMY

MPERMY - Flag indicating whether the absolute permeabilities in the Y-direction are homogeneous or heterogeneous.

Possible Values:

0 : Permeabilities in the Y-direction are homogeneous

1 : Permeabilities in the Y-direction are heterogeneous

2 : Permeabilities in the Y-direction varies in the Z-direction

3 : Y direction permeability values for each gridblock are read from PERMY input file

4 : Y direction permeability is dependent on X direction permeability

If MPERMY=1 or MPERMY >3 skip to 3.3.30; if MPERMY=2, skip to 3.3.31

3.3.29 PERMY (This line is read only if MPERMY=0)
PERMY – Constant absolute permeabilities of all grid blocks in the Y-direction.
Units: mD
Note: If MPERMY=0 (the absolute permeability in the Y-direction is homogeneous), only one value is required by the program.

3.3.30 PERMY(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if MPERMY=1)
PERMY(I) – NB Values of absolute permeabilities of every grid blocks in the Y-direction.
Units: mD
Note: If MPERMY =1 (the absolute permeability in the Y-direction is heterogeneous), NB values for are required by the program.
Note: If MPERMY =3, Y direction permeability values for each gridblock are read from PERMY input file
Note: If MPERMY =4, Constant permeability multiplier for Y direction permeability. The X direction permeabilities are multiplied by FACTY to obtain the Y direction permeabilities.

3.3.31 PERMY(LZ), LZ = 1, NZ (This line is read only if MPERMY=2)
PERMY(LZ) – NZ Values of absolute permeabilities of every layer in the Y-direction.
Units: fraction
Note: If MPERMY =2 (values vary in the Z-direction), NZ values are required by the program.

3.3.32 MPERMZ
MPERMZ - Flag indicating whether the absolute permeabilities in the Z-direction are homogeneous or heterogeneous.
Possible Values:
0 : Permeabilities in the Z-direction are homogeneous
1 : Permeabilities in the Z-direction are heterogeneous
2 : Permeabilities in the Z-direction varies in the Z-direction
3 : Z direction permeability values for each gridblock are read from PERMZ input file
4 : Z direction permeability is dependent on X direction permeability

If MPERMZ=1 or MPERMZ >3 skip to 3.3.34; if MPERMZ=2, skip to 3.3.35

3.3.33 PERMZ (This line is read only if MPERMZ=0)
PERMZ – Constant absolute permeabilities of all grid blocks in the Z-direction.
Units: mD
Note: If MPERMZ=0 (the absolute permeability in the Z-direction is homogeneous), only one value is required by the program.

3.3.34 PERMZ(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if MPERMZ=1)

PERMZ(I) – NB Values of absolute permeabilities of every grid blocks in the Z- direction.

Units: mD

Note: If MPERMZ =1 (the absolute permeability in the Z-direction is heterogeneous), NB values for are required by the program.

Note: If MPERMZ =3, Y direction permeability values for each gridblock are read from PERMZ input file

Note: If MPERMZ =4, Constant permeability multiplier for Y direction permeability. The X direction permeabilities are multiplied by FACTZ to obtain the Z direction permeabilities.

3.3.35 PERMZ(LZ), LZ = 1, NZ (This line is read only if MPERMZ=2)

PERMZ(LZ) – NZ Values of absolute permeabilities of every layer in the Z-direction.

Units: fraction

If MPERMZ =2 (values vary in the Z-direction), NZ values are required by the program.

Reservoir Property Modification Data— This section is required only if MMOD=1.

IMPOR, IMKX, IMKY, IMKZ, IMSW (This line is read only if MMOD=1)

IMPOR - Flag indicating whether the porosity is modified or not.

Possible Values:

0 - No modification is considered in porosity values

1 - Allow modification in porosity

IMKX- Flag indicating whether the permeability in the X direction is modified or not.

Possible Values:

0 - No modification is considered in X permeability

1 - Allow modification in X permeability

IMKY- Flag indicating whether the permeability in the Y direction is modified or not.

Possible Values:

0 - No modification is considered in Y permeability

1 - Allow modification in Y permeability

IMKZ- Flag indicating whether the permeability in the Z direction is modified or not.

Possible Values:

0 - No modification is considered in Z permeability

1 - Allow modification in Z permeability

IMSW- Flag indicating whether the initial water saturation is modified or not.

Possible Values:

0 - No modification is considered in initial water saturation values

1 - Allow modification in initial water saturation

3.3.36 NMOD0 (This line is read only if IMOD=1 and IMPOR=1)
NMOD0 - Number of regions with modified porosity.

3.3.37 IMIN, IMAX, JMIN, JMAX, KMIN, KMAX, IFACT, FACTX (This line is read only if IMOD=1 and NMOD0>0)
IMIN - The first index in X direction.
IMAX - The last index in X direction.
JMIN - The first index in Y direction.
JMAX - The last index in Y direction.
KMIN - The first index in Z direction.
KMAX - The last index in Z direction.
IFACT - Flag indicating how porosity is modified.
Possible Values:
1 - Replace porosity with FACTX
2 - Multiply porosity by FACTX
3 - Add FACTX to porosity

3.3.38 NMOD1 (This line is read only if IMOD=1 and IMKX=1)
NMOD1 - Number of regions with modified X permeability.

3.3.39 IMIN, IMAX, JMIN, JMAX, KMIN, KMAX, IFACT, FACTX (This line is read only if IMOD=1 and NMOD1>0)
IMIN - The first index in X direction.
IMAX - The last index in X direction.
JMIN - The first index in Y direction.
JMAX - The last index in Y direction.
KMIN - The first index in Z direction.
KMAX - The last index in Z direction.
IFACT - Flag indicating how X permeability is modified.
Possible Values:
1 - Replace X permeability with FACTX
2 - Multiply X permeability by FACTX
3 - Add FACTX to X permeability

3.3.40 NMOD2 (This line is read only if IMOD=1 and IMKX=1)
NMOD2 - Number of regions with modified Y permeability.

3.3.41 IMIN, IMAX, JMIN, JMAX, KMIN, KMAX, IFACT, FACTX (This line is read only if IMOD=1 and NMOD2>0)
IMIN - The first index in X direction.
IMAX - The last index in X direction.
JMIN - The first index in Y direction.
JMAX - The last index in Y direction.
KMIN - The first index in Z direction.
KMAX - The last index in Z direction.
IFACT - Flag indicating how Y permeability is modified.

Possible Values:

1 - Replace Y permeability with FACTX
2 - Multiply Y permeability by FACTX
3 - Add FACTX to Y permeability

3.3.42 NMOD3 (This line is read only if IMOD=1 and IMKX=1)

NMOD3 - Number of regions with modified Z permeability.

3.3.43 IMIN, IMAX, JMIN, JMAX, KMIN, KMAX, IFACT, FACTX (This line is read only if IMOD=1 and NMOD3>0)

IMIN - The first index in X direction.
IMAX - The last index in X direction.
JMIN - The first index in Y direction.
JMAX - The last index in Y direction.
KMIN - The first index in Z direction.
KMAX - The last index in Z direction.
IFACT - Flag indicating how Z permeability is modified.
Possible Values:

1 - Replace Z permeability with FACTX
2 - Multiply Z permeability by FACTX
3 - Add FACTX to Z permeability

3.3.44 NMOD4 (This line is read only if IMOD=1 and IMKX=1)

NMOD4 - Number of regions with modified initial water saturation.

3.3.45 IMIN, IMAX, JMIN, JMAX, KMIN, KMAX, IFACT, FACTX (This line is read only if IMOD=1 and NMOD4>0)

IMIN - The first index in X direction.
IMAX - The last index in X direction.
JMIN - The first index in Y direction.
JMAX - The last index in Y direction.
KMIN - The first index in Z direction.
KMAX - The last index in Z direction.
IFACT - Flag indicating how initial water saturation is modified.
Possible Values:

1 - Replace initial water saturation with FACTX
2 - Multiply initial water saturation by FACTX
3 - Add FACTX to initial water saturation

3.3.46 MCF, CF, PF

3.3.46a MCF

MCF- Flag indicating whether the formation compressibility is constant or variable.
Possible Values:

0 - The Formation compressibility is constant at reservoir datum

1 - The Formation compressibility is variable

3.3.46b CF

CF - Formation compressibility.

Units: psi^{-1}

Note: If MCF = 1, NB values are required by the program.

3.3.46c PF

PF - Formation reference pressure at reservoir datum.

Units: psi

3.3.47 CW, PW, DENMWS

CW - Water compressibility.

Units: psi^{-1}

PW - Water reference pressure.

Units: psi

DENMWS - Water molar density.

Units: $lb\text{-}moles/ft^3$

3.3.48 WTW, VISCW

WTW - Molecular weight of water.

Units: lbm/lb-mole

VISCW - Water viscosity.

Units: cp

3.3.49 TEMPF

TEMPF - Reservoir temperature.

Units: ˚ F

3.3.50 TFSTD, PSTD

TFSTD - Standard temperature.

Units: ˚ F

PSTD - Standard pressure.

Units: psi

3.3.51 IUPSTW

IUPSTW - Flag indicating method of numerical dispersion control to be used.

Possible Values:

1 : One-point upstream weighted method used
2 : Two-point upstream weighted method used
3 : Exponential upstream weighted third order method used
4 : Total variation diminishing third order method used

3.3.52 ITC

ITC - Flag indicating whether 1^{st} or 2^{nd} order time approximation is used.

Possible Values:

0 : 1^{st} order time approximation used
1 : 2^{nd} order time approximation used

3.3.53 ISTART, ISTORE

ISTART - Flag indicating whether the initial reservoir conditions to be used for the current run are in this input file or a restart file.

Possible Values:

1 : Initial conditions for the current run are contained in this input file

2 : Initial conditions for the current run are the final results of a previous run, stored in TEST.STO, the RESTART file

ISTORE - Flag indicating whether restart information will be written to a file or not.

Possible Values:

0 : Do not write the restart information to a file—note that if this information is not written to a file, the current simulation cannot be continued at some future date

1 : Write restart information to STORE file

3.3.54 MDT

MDT - Flag indicating whether automatic time step selector will be used or not.

Possible Values:

0 : Automatic time step selector is not used and time step is specified by DT on input line 3.4.1

1 : Automatic time step selector is used and time step will be computed by program according to the parameters specified on input line 3.4.3

3.3.55 MDISP

MDISP - Flag indicating whether physical dispersion will be computed or not.

Possible Values:

0 : Physical dispersion will not be computed

1 : Physical dispersion will be computed

2 : Physical dispersion will be computed using Young's dispersion model—central difference

3 : Physical dispersion will be computed using Young's dispersion model—backward difference

4 : Physical dispersion will be computed using Young's dispersion model—forward difference

<u>If MDISP=0 skip to 3.3.60</u>

3.3.56 DIFFUN(J,I), for I=1, NC, for J=1, NP (This line is read only if MDISP ≠ 0)

DIFFUN(J,I) - Molecular diffusion coefficient for I^{th} component in J^{th} phase.

Units: ft^2/day

Example Value: 0.0

Note: All component molecular diffusion coefficients of phase 1 are read, then those for phase 2, etc.

3.3.57 TAU (This line is read only if MDISP ≠ 0)

TAU - Tortuosity factor.
Example Value: 1.0

3.3.58 ALPHAL(J), ALPHAT(J), for J=1, NP (This line is read only if MDISP ≠ 0)
ALPHAL(J) - Longitudinal dispersivity of J^{th} phase.
Units: ft
Example Value: 3.0
ALPHAT(J) - Transverse dispersivity of J^{th} phase.
Units: ft
Example Value: 03

3.3.59 BETAL, BETAT, ALMAX, ATMAX (This line is read only if MDISP ≠ 0)
BETAL - Longitudinal parameter for Young's dispersion model.
Units: ft
Example Value: 0.0
BETAT - Transverse parameter for Young's dispersion model.
Units: ft
Example Value: 0.0
ALMAX - Longitudinal limit on effective dispersivity for Young's dispersion model.
Units: ft
Example Value: 0.1
ATMAX - Transverse limit on effective dispersivity for Young's dispersion model.
Units: ft
Example Value: 0.005
Note: These values are only used by the program when MDISP=2, 3, or 4.

Relative Permeability

The following table summarizes the available relative permeability models and the hysteresis options in the DOECO2.

				Hysteresis Models[1]			
Model	IPEM	ICAP[2]	Composition Dependent	IHYSTPH=1[3]	IHYSTPH=2[4]	IHYSTPH=3[5]	IHYSTPH=4[6]
Baker	1	0 or 1	NO	NO	NO	NO	NO
Modified Stone II	2	0 or 1	NO	NO	NO	NO	NO
Corey	3	0 or 1	NO	YES	YES	YES	NO
Modified Corey[7]	4	0 or 1	NO	YES	YES	YES	NO

Pope & Chengwu	5	NO	YES[8]	NO	NO	NO	NO
Jerauld	6	NO[9]	NO[10]	YES[11]	NO	NO	NO
UTKR3P	7	0 or 2	YES[8]	YES	YES	YES	YES
Lookup Table[12]	8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

1) No hysteresis for all phases (IHYST=0) and No Hysteresis for specific phase IHYSTPH(j)=0
2) ICAP=0: NO Capillary or Trapping number Effect, ICAP=1: Capillary Number Dependency, ICAP=2: Trapping Number Dependency
3) Hysteresis model (Saturation direction dependent) for intermediate- and non- wetting phases (Carlson, 1981)
4) Hysteresis model to add the effect of trapped gas on oil residual sat. (Fayers and Matthews, 1984)
5) Hysteresis model resulting in a cycle dependent relative permeability (Saturation direction and saturation path dependent) for water as wetting phase and gas as non-wetting phase (Larsen and Skauge, 1998)
6) Hysteresis model resulting in a cycle dependent relative permeability (Saturation direction and saturation path dependent) for intermediate- and non- wetting phases (Beygi & Delshad, 2012)
7) Predicting the three-phase relative permeabilities in CO_2 floods based on extension of the Brooks and Corey (1986) (Daria, 1990)
8) Based on Gibbs free energy. (Chengwu and Pope, 2010). IPERM=7 will have this composition dependency as an option
9) Original model has capillary number dependency. However, it is not implemented into DOECO2
10) Original model has composition consistency based on parachor-weighted molar density. However, it is not implemented into DOECO2.
11) The model has an inherent hysteresis for the gaseous phases. This behavior can be called off if [IHYSTPH(3)=0]
12) Implement and couple with IPERM=2 and 7. (To be added)

3.3.60 IPERM, ICPRES, ICAP, IRPERM, IRTYPE, IHYST

IPERM - Flag indicating which relative permeability model is to be used.

Possible Values:

1 : Baker's model will be used
2 : Modified Stone's Model II will be used
3 : Corey's model will be used
4 : Modified Corey's model will be used
5 : Pope and Chengwu's model will be used
6 : Jerauld model will be used
7 : UTKR3PIPERM=4 model will be used

ICPRES - Flag indicating whether capillary pressures are computed or not.
Possible Values:
0 : Capillary pressures will not be computed
1 : Capillary pressures will be computed (not applicable to IPERM=5, 6)

ICAP - Flag indicating whether residual saturations and relative permeabilities are dependent on capillary number or not (capillary desaturation effects).
Possible Values:
0 : Residual saturations and relative permeabilities are not dependent on capillary number or trapping number
1 : Residual saturations and relative permeabilities are dependent on capillary number
2 : Residual saturations and relative permeabilities are dependent on trapping Number (see Table above)

IRPERM - Flag indicating whether the parameters of the relative permeability models are constant or not.
Possible Values:
0 : The parameters of the relative permeability model are constant
1 : The parameters of the relative permeability model vary in the Z-direction
2 : The parameters of the relative permeability model vary for each grid block

IRTYPE- Flag indicating if the rock type option is used
Possible Values:
0 - Rock type option is not used
1 - Rock type option is used

If IRTYPE=1, go to 3.3.101

IHYST- Hysteresis option in Corey, Jerauld, and UTKR3P relative permeability models

Possible Values:
0 : No hysteresis in the relative permeability
1 : hysteresis will be implemented

3.3.60a EPC, CPC (This line is read only if ICPRES= 1)
EPC - Capillary pressure function exponent, E_{pc}.
Units: dimensionless
Example Value: 2
CPC - Capillary pressure function parameter, C_{pc}.
Units: psi $(md)^{0.5}$/dyne/cm
Example Value: 1.0

3.3.60b RIFTWO, RIFTWG, RIFTWL (This line is read only if ICPRES=1 or ICAP=1)
RIFTWO - Water-oil interfacial tension, σ_{12}
Units: dynes/cm
Example Value: 42
RIFTWG - Water-gas interfacial tension, σ_{13}
Units: dynes/cm
Example Value: 24
RIFTWL - Water-second liquid interfacial tension, σ_{14} (This parameter is read only NP=4)

Units: dynes/cm
Example Value: 30

If IPERM=7 skip to 3.3.61

3.3.60c S1RW, S2RW1, S2RW2, S3RW, S4RW1, S4RW2 << or >>
S1RW(I), S2RW1(I), S2RW2(I), S3RW(I), S4RW1(I), S4RW2(I), for I=1, NZ
<< or >>
S1RW(I), S2RW1(I), S2RW2(I), S3RW(I), S4RW1(I), S4RW2(I), for I=1, NB where NB=NX × NY × NZ

S1RW or S1RW(I) - Water residual saturation for water-liquid hydrocarbon flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.35

S2RW1 or S2RW1(I) - Oil residual saturation for water-oil flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.36

S2RW2 or S2RW2(I) - Oil residual saturation for gas-oil flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.25

S3RW or S3RW(I) - Gas residual saturation for gas-liquid hydrocarbon flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S4RW1 or S4RW1(I) - Second liquid residual saturation for water-second liquid flow at low capillary number for all grid blocks or I^{th} grid block (see note).

Example Value: 0.18

S4RW2 or S4RW2(I) - Second liquid residual saturation for gas-second liquid flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.15

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

If ICAP=0 skip to 3.3.60e

3.3.60d S1RC, S2RC1, S2RC2, S3RC, S4RC1, S4RC2 << or >>
S1RC(I), S2RC1(I), S2RC2(I), S3RC(I), S4RC1(I), S4RC2(I), for I=1, NZ << or >>
S1RC(I), S2RC1(I), S2RC2(I), S3RC(I), S4RC1(I), S4RC2(I), for I=1, NB where NB=NX × NY × NZ

S1RC or S1RC(I) - Water residual saturation for water-liquid hydrocarbon flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S2RC1 or S2RC1(I) - Oil residual saturation for water-oil flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S2RC2 or S2RC2(I) - Oil residual saturation for gas-oil flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S3RC or S3RC(I) - Gas residual saturation for gas-liquid hydrocarbon flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S4RC1 or S4RC1(I) - Second liquid residual saturation for water-second liquid flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

S4RC2 or S4RC2(I) - Second liquid residual saturation for gas-second liquid flow at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.60e P1RW, P2RW, P3RW, P4RW << or >>
P1RW(I), P2RW(I), P3RW(I), P4RW(I), for I=1, NZ << or >>
P1RW(I), P2RW(I), P3RW(I), P4RW(I), for I=1, NB where NB=NX × NY × NZ

P1RW or P1RW(I) - End point water relative permeability at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 0.1

P2RW or P2RW(I) - End point oil relative permeability at low capillary number for all grid

blocks or I^{th} grid block (see note).
Example Value: 1.0

P3RW or P3RW(I) - End point gas relative permeability at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

P4RW or P4RW(I) - End point second hydrocarbon liquid relative permeability at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the relative permeabilities is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the relative permeabilities for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the relative permeabilities for each grid block.

If ICAP=0 skip to 3.3.60g

3.3.60f P1RC, P2RC, P3RC, P4RC << or >>
P1RC(I), P2RC(I), P3RC(I), P4RC(I), for I=1, NZ << or >>
P1RC(I), P2RC(I), P3RC(I), P4RC(I), for I=1, NB where NB=NX × NY × NZ

P1RC or P1RC(I) - End point water relative permeability at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

P2RC or P2RC(I) - End point oil relative permeability at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

P3RC or P3RC(I) - End point gas relative permeability at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

P4RC or P4RC(I) - End point second hydrocarbon liquid relative permeability at high capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the relative permeabilities is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the relative permeabilities for each grid block in the Z-direction

must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the relative permeabilities for each grid block.

3.3.60g E1W, E2W1, E2W2, E3W, E4W1, E4W2 << or >>
E1W(I), E2W1(I), E2W2(I), E3W(I), E4W1(I), E4W2(I), for I=1, NZ << or >>
E1W(I), E2W1(I), E2W2(I), E3W(I), E4W1(I), E4W2(I), for I=1, NB where NB=NX × NY × NZ

E1W or E1W(I) - Exponent of water relative permeability for water-liquid hydrocarbon flow at low capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 3

E2W1 or E2W1(I) - Exponent of oil relative permeability for water-oil flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 3

E2W2 or E2W2(I) - Exponent of oil relative permeability for gas-oil flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 3

E3W or E3W(I) - Exponent of gas relative permeability for gas-liquid hydrocarbon flow at low capillary number for all grid blocks or I^{th} grid block (see note).
Example Value: 2

E4W1 or E4W1(I) - Exponent of second liquid relative permeability for water-second liquid flow at low capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 2

E4W2 or ERW2(I) - Exponent of second liquid relative permeability for gas-second liquid flow at low capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 2

Note: If IRPERM=0 (values are constant), only one value for each of the exponents related to relative permeabilities is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the exponents related to relative permeabilities for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the exponents related to relative permeabilities for each grid block.

If ICAP=0 skip to 3.3.60i

3.3.60h E1C, E2C1, E2C2, E3C, E4C1, E4C2 << or >>
E1C(I), E2C1(I), E2C2(I), E3C(I), E4C1(I), E4C2(I), for I=1, NZ << or >>

E1C(I), E2C1(I), E2C2(I), E3C(I), E4C1(I), E4C2(I), for I=1, NB where NB=NX × NY × NZ

E1C or E1C(I) - Exponent of water relative permeability for water-liquid hydrocarbon flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

E2C1 or E2C1(I) - Exponent of oil relative permeability for water-oil flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

E2C2 or E2C2(I) - Exponent of oil relative permeability for gas-oil flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

E3C or E3C(I) - Exponent of gas relative permeability for gas-liquid hydrocarbon flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

E4C1 or E4C1(I) - Exponent of second liquid relative permeability for water-second liquid flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

E4C2 or E4C2(I) - Exponent of second liquid relative permeability for gas-second liquid flow at high capillary number for all grid blocks or I^{th} grid block (see note). Example Value: 1

Note: If IRPERM=0 (values are constant), only one value for each of the exponents related to relative permeabilities is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the exponents related to relative permeabilities for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the exponents related to relative permeabilities for each grid block.

3.3.60i T11, T12, T211, T221, T212, T222

T11 - Slope of water capillary desaturation curve. Example Value: 250

T12 - End point capillary number of water capillary desaturation curve. Example Value: 1.0

T211 - Slope of oil capillary desaturation curve for water-oil flow. Example Value: 3000

T221 - End point capillary number of oil capillary desaturation curve for water-oil flow.
Example Value: 1.0

T212 - Slope of oil capillary desaturation curve for gas-oil flow.
Example Value: 3000

T222 - End point capillary number of oil capillary desaturation curve for gas-oil flow.
Example Value: 1.0

Note: To suppress the capillary desaturation effect, set Tlij equal to zero

3.3.60j T31, T32, T411, T421, T412, T422

T31 - Slope of gas capillary desaturation curve.
Example Value: 25000

T32 - End point capillary number of gas capillary desaturation curve.
Example Value: 1.0

T411 - Slope of second liquid capillary desaturation curve for water-second liquid flow.
Example Value: 100

T421 - End point capillary number of second liquid capillary desaturation curve for water-second liquid flow.
Example Value: 1.0

T412 - Slope of second liquid capillary desaturation curve for gas-second liquid flow.
Example Value: 100

T422 - End point capillary number of second liquid capillary desaturation curve for gas-second liquid flow.
Example Value: 1.0

Note: To suppress the capillary desaturation effect, set Tlij equal to zero

Note: If IRPERM=0 (values are constant), only one value for each of the parameters related to Pope's model is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the parameters related to Pope's model for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the parameters related to Pope's model for each grid block.

If IPERM≠7, skip to 3.3.99

3.3.61 S1RW2, S1RW3, S2RW1, S2RW3, S3RW1, S3RW2 << or >>
S1RW2(I), S1RW3(I), S2RW1(I), S2RW3(I), S3RW1(I), S3RW2(I) for I=1, NZ << or >>
S1RW2(I), S1RW3(I), S2RW1(I), S2RW3(I), S3RW1(I), S3RW2(I) for I=1, NB
(This line is read only if IPERM=7)
S1RW2- Water residual saturation in water-oil flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S1RW3- Water residual saturation in water-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S2RW1- Oil residual saturation in oil-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S2RW3- Oil residual saturation in oil-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S3RW1- Gas residual saturation in gas-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S3RW2- Gas residual saturation in gas-oil flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

If ICAP=0, skip to 3.3.63

3.3.62 S1RC2, S1RC3, S2RC1, S2RC3, S3RC1, S3RC2 << or >>
S1RC2(I), S1RC3(I), S2RC1(I), S2RC3(I), S3RC1(I), S3RC2(I) for I=1, NZ << or >>
S1RC2(I), S1RC3(I), S2RC1(I), S2RC3(I), S3RC1(I), S3RC2(I) for I=1, NB
(This line is read only if IPERM=7)
S1RC2- Water residual saturation in water-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S1RC3- Water residual saturation in water-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S2RC1- Oil residual saturation in oil-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0
S2RC3- Oil residual saturation in oil-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 0.0

S3RC1- Gas residual saturation in gas-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0

S3RC2- Gas residual saturation in gas-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 0.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.63 P1RW2, P1RW3, P2RW1, P2RW3, P3RW1, P3RW2 << or >>
P1RW2(I), P1RW3(I), P2RW1(I), P2RW3(I), P3RW1(I), P3RW2(I) for I=1, NZ
<< or >> P1RW2(I), P1RW3(I), P2RW1(I), P2RW3(I), P3RW1(I), P3RW2(I) for I=1, NB
(This line is read only if IPERM=7)

P1RW2- End point water relative permeability in water-oil flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

P1RW3- End point water relative permeability in water-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

P2RW1- End point oil relative permeability in oil-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

P2RW3- End point oil relative permeability in oil-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

P3RW1- End point gas relative permeability in gas-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

P3RW2- End point gas relative permeability in gas-oil flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

If ICAP=0, skip to 3.3.65

3.3.64 PR1C2, PR1C3, PR2C1, PR2C3, PR3C1, PR3C2 << or >>
PR1C2(I), PR1C3(I), PR2C1(I), PR2C3(I), PR3C1(I), PR3C2(I) for I=1, NZ

<< or >> PR1C2(I), P1R1C3(I), PR2C1(I), PR2C3(I), PR3C1(I), PR3C2(I) for I=1, NB
(This line is read only if IPERM=7)

PR1C2- End point water relative permeability in water-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

PR1C3- End point water relative permeability in water-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

PR2C1- End point oil relative permeability in oil-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

PR2C3- End point oil relative permeability in oil-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

PR3C1- End point gas relative permeability in gas-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

PR3C2- End point gas relative permeability in gas-oil flow at high trapping for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.65 C11W2, C11W3, C12W1, C12W3, C13W1, C13W2 << or >>
C11W2(I), C11W3(I), C13W1(I), C13W3(I), C13W31(I), C13W2(I) for I=1, NZ
<< or >> C11W2(I), C11W3(I), C12W1(I), C12W3(I), C13W1(I), C13W2(I) for I=1, NB
(This line is read only if IPERM=7)

C11W2- "C_1" water coefficient in water-oil flow at low trapping numbe for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C11W3- "C_1" water coefficient in water-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C12W1- "C_1" oil coefficient in oil-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C12W3- "C_1" oil coefficient in oil-gas flow at low trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C13W1- "C_1" gas coefficient in gas-water flow at low trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C13W2- "C_1" gas coefficient in gas-oil flow at low trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

If ICAP=0, skip to 3.3.67

3.3.66 C11C2, C11C3, C12C1, C12C3, C13C1, C13C2 << or >>
C11C2(I), C11C3(I), C12C1(I), C12C3(I), C31C1(I), C31C2(I) for I=1, NZ << or >>
C11C2(I), C11C3(I), C12C1(I), C12C3(I), C13C1(I), C13C2(I) for I=1, NB **(This line is read only if IPERM=7)**

C11C2- "C_1" water coefficient in water-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C11C3- "C_1" water coefficient in water-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C12C1- "C_1" oil coefficient in oil-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C12C3- "C_1" oil coefficient in oil-gas flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C13C1- "C_1" gas coefficient in gas-water flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C13C2- "C_1" gas coefficient in gas-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.67 C21W2, C21W3, C22W1, C22W23, C23W1, C23W2 << or >>
C21W2(I), C21W3(I), C22W1(I), C22W3(I), C23W1(I), C23W2(I) for I=1, NZ
<< or >> C21W2(I), C21W3(I), C22W1(I), C22W3(I), C23W1(I), C23W2(I) for I=1, NB
(This line is read only if IPERM=7)

C21W2- "C_2" water coefficient in water-oil flow at low trapping number

for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C21W3- "C_2" water coefficient in water-gas flow at low trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C22W1- "C_2" oil coefficient in oil-water flow at low trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C22W3- "C_2" oil coefficient in oil-gas flow at low trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C23W1- "C_2" gas coefficient in gas-water flow at low trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C23W2- "C_2" gas coefficient in gas-oil flow at low trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.

If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.

If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

If C_{2ji}=0, UTKR3P model will be similar to Corey relative permeability model for that specific phase 'j' except for the normalized saturation definition.

If ICAP=0, skip to 3.3.70

3.3.68 C21C2, C21C3, C22C1, C22C3, C23C1, C23C2 << or >>
C21C2(I), C21C3(I), C22C1(I), C22C3(I), C23C1(I), C23C2(I) for I=1, NZ
<< or >> C21C2(I), C21C3(I), C22C1(I), C22C3(I), C23C1(I), C23C2(I) for I=1, NB
(This line is read only if IPERM=7)

C21C2- "C_2" water coefficient in water-oil flow at high trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C21C3- "C_2" water coefficient in water-gas flow at high trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C22C1- "C_2" oil coefficient in oil-water flow at high trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C22C3- "C_2" oil coefficient in oil-gas flow at high trapping number
for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

C23C1- "C_2" gas coefficient in gas-water flow at high trapping number
for all gridblocks or I^{th} grid block (see note)

Example value: 1.0

C23C2- "C_2" gas coefficient in gas-oil flow at high trapping number for all gridblocks or I^{th} grid block (see note)
Example value: 1.0

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.69 S1C, S2C, and S3C (This line is read only if IPERM=7)

S1C- Connate water saturation
Example value: 0.0

S2C- Critical oil saturation
Example value: 0.0

S3C- Critical gas saturation
Example value: 0.0

3.3.70 BSR1, BSR2, BSR3 << or >>
BSR1(I), BSR2 (I), BSR3(I) for I=1, NZ << or >>
BSR1(I), BSR2 (I), BSR3(I) for I=1, NB **(This line is read only if IPERM=7)**

BSR1- "b_1" coefficient relating water residual saturation in three-phase flow to that of two-phase flow (see note)
Example value: 1.0

BSR2- "b_2" coefficient relating oil residual saturation in three-phase flow to that of two-phase flow (see note)
Example value: 1.0

BSR3- "b_3" coefficient relating gas residual saturation in three-phase flow to that of two-phase flow (see note)
Example value: 1.0

ISR2P- Flag indicating the calculation method for the two-phase residual saturation to be used in three-phase residual saturation equation
Possible Values:

0: Two-phase residual saturation is a fixed value calculated by

$$S_{jr}^{2P} = \max(S_{jrm}, S_{jrl})$$

1: Two-phase residual saturation is variable and is calculated based on a saturation- average method

$$S_{jr}^{2P} = \frac{(S_m - S_{mc})S_{jrm}^{*} + (S_l - S_{lc})S_{jrl}^{*}}{1 - S_j - S_{mc} - S_{lc}}$$

Note: If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define

the residual saturations for each grid block.

For each phase, "b_j" parameter must be less than $\frac{1}{(1-S_{mc}-S_{jc})(1-S_{lc}-S_{jc})}$ to avoid negative three-phase residual saturation. For simplicity, take $b \leq 1$.

ISR3P- Flag indicating the effect of current saturation on the three-phase residual saturation

Possible Values:

0: Three-phase residual saturation will be calculated by

$$S_{jr}^{3P} = \min\left\{S_j, max\left\{S_{jc}, S_{jr}^{2P}\left(1 - b_j(max(S_m, S_{mc}) - S_{mc})(max(S_l, S_{lc}) - S_{lc})\right)\right\}\right\}$$

1: Three-phase residual saturation will be calculated by

$$S_{jr}^{3P} = max\left\{S_{jc}, S_{jr}^{2P}\left(1 - b_j(max(S_m, S_{mc}) - S_{mc})(max(S_l, S_{lc}) - S_{lc})\right)\right\}$$

3.3.71 IPR3P, IC13P, and IC23P

IPR3P- Flag indicating whether phase end point relative permeability in three-phase flow is estimated or predefined.

Possible Values:

0: Three-phase end-point relative permeability for all phases is estimated based on saturation averaged interpolation between the two-phase endpoint rel. permeabilities

100: Water endpoint relative permeability for three-phase flow is defined explicitly on input line(s) 3.3.72 and 3.3.73

010: Oil endpoint relative permeability for three-phase flow is defined explicitly on input line(s) 3.3.74. and 3.3.75

001: Gas endpoint relative permeability for three-phase flow is defined explicitly on input line(s) 3.3.76 and 3.3.77

110: Water and oil endpoint relative permeabilities in three-phase flow are defined explicitly on input lines 3.3.72, 3.3.73, 3.3.74, and 3.3.75

101: Water and gas endpoint relative permeabilities in three-phase flow are defined explicitly on input lines 3.3.72, 3.3.73, 3.3.76, and 3.3.77

011: Oil and gas endpoint relative permeabilities in three-phase flow are defined explicitly on input lines 3.3.74, 3.3.75, 3.3.76, and 3.3.77

111: Water, oil and gas endpoint relative permeabilities in three-phase flow are defined explicitly on input lines 3.3.72 to 3.3.77

IC13P- Flag indicating whether "C_l" coefficients for each phase in three-phase flow is estimated or predefined.

Possible Values:

0: "C_l" coefficient for each phase in three-phase flow is estimated based on saturation averaged interpolation between the two-phase "C_l" coefficients

100: "C_l" coefficient for aqueous phase in three-phase flow is defined explicitly on input line(s) 3.3.78 and 3.3.79

010: "C_l" coefficient for oleic phase in three-phase flow is defined explicitly on input line(s) 3.3.80 and 3.3.81

001: "C_l" coefficient for gaseous phase in three-phase flow is defined explicitly on input line(s) 3.3.82 and 3.3.83

110: Water and oil "C_l" coefficients in three-phase flow are defined explicitly

on input lines 3.3.78, 3.3.79, 3.3.80, and 3.3.81

101: Water and gas "C_1" coefficients in three-phase flow are defined explicitly on input lines 3.3.78, 3.3.79, 3.3.82, and 3.3.83

011: Oil and gas "C_1" coefficients in three-phase flow are defined explicitly on input lines 3.3.80, 3.3.81, 3.3.82, and 3.3.83

111: Water, oil and gas "C_1" coefficients in three-phase flow are defined explicitly on input lines to 3.3.83

IC23P- Flag indicating whether "C_2" coefficients for each phase in three-phase flow is estimated or predefined.

Possible Values:

0: "C_2" coefficient for each phase in three-phase flow is estimated based on saturation averaged interpolation between the two-phase "C_2" coefficients

100: Water "C_2" coefficient in three-phase flow is defined explicitly on input line(s) 3.3.67 and 3.3.85

010: Oil "C_2" coefficient in three-phase flow is defined explicitly on input line(s) 3.3.86 and 3.3.87

001: Gas "C_2" coefficient in three-phase flow is defined explicitly on input line(s) 3.3.88 and 3.3.89

110: Water and oil "C_2" coefficients in three-phase flow are defined explicitly on input lines 3.3.84, 3.3.85, 3.3.86, and 3.3.87

101: Water and gas "C_2" coefficients in three-phase flow are defined explicitly on input lines 3.3.84, 3.3.85, 3.3.88, and 3.3.89

011: Oil and gas "C_2" coefficients in three-phase flow are defined explicitly on input lines 3.3.86, 3.3.87, 3.3.88, and 3.3.89

111: Water, oil and gas "C_2" coefficients in three-phase flow are defined explicitly on input lines 3.3.84 to 3.3.89

Note: "0" indicates that phase(s) property is calculated and "1" indicates that phase property is set explicitly for three-phase flow.

If IPR3P=0, 010, 001, or 011 skip to 3.3.74

3.3.72 PR1W3P (This line is read only if IPERM=7 and IPR3P=100, 101, 110, or 111)

PR1W3P- End point water relative permeability in three phase flow at low trapping number for all grid blocks or I^{th} grid block

Example value: 1.0

If IPR3P=0, 010, 001, or 011 or ICAP=0 skip to 3.3.74

3.3.73 PR1C3P (This line is read only if IPERM=7 and IPR3P=100, 101, 110, or 111 and ICAP≠0)

PR1C3P- End point water relative permeability in three phase flow at high trapping number for all grid blocks or I^{th} grid block

Example value: 1.0

If IPR3P=0, 100, 001, or 101 skip to 3.3.76

3.3.74 PR2W3P (This line is read only if IPERM=7 and IPR3P=010, 110, 011, or 111)

PR2W3P- End point oil relative permeability in three phase flow at low trapping number for all grid blocks or Ith grid block
Example value: 1.0

If IPR3P=0, 100, 001, or 101 or ICAP=0 skip to 3.3.76

3.3.75 PR2C3P (This line is read only if IPERM=7 and IPR3P=010, 110, 011, or 111 and ICAP≠0)
PR2C3P- End point oil relative permeability in three phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IPR3P=0, 100, 010, or 110 skip to 3.3.76

3.3.76 PR3W3P (This line is read only if IPERM=7 and IPR3P=001, 101, 011, or 111)
PR3W3P- End point gas relative permeability in three phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IPR3P=0, 100, 010, or 110 or ICAP=0 skip to 3.3.78

3.3.77 PR3C3P (This line is read only if IPERM=7 and IPR3P=001, 101, 011, or 111)
PR3C3P- End point gas relative permeability in three phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 010, 001, or 011 skip to 3.3.80

3.3.78 C11W3P (This line is read only if IPERM=7 and IC13P=100, 101, 110, or 111)
C11W3P- "C_1" coefficient for aqueous phase in three-phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 010, 001, or 011 or ICAP=0 skip to 3.3.80

3.3.79 C11C3P (This line is read only if IPERM=7 and IC13P=100, 101, 110, or 111 and ICAP≠0)
C11C3P- "C_1" coefficient for aqueous phase in three-phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 100, 001, or 101 skip to 3.3.82

3.3.80 C12W3P (This line is read only if IPERM=7 and IC13P=010, 110, 011, or 111)
C12W3P - "C_1" coefficient for oleic phase in three-phase flow at low trapping number for all gridblocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 100, 001, or 101 or ICAP=0 skip to 3.3.82

3.3.81 C12C3P (This line is read only if IPERM=7 and IC13P=010, 110, 011, or 111 and ICAP≠0)
C12C3P- "C_1" coefficient for oleic phase in three-phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 100, 010, or 110 skip to 3.3.84

3.3.82 C13W3P (This line is read only if IPERM=7 and IC13P=001, 101, 011, or 111)
C13W3P- "C_1" coefficient for gaseous phase in three-phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC13P=0, 100, 010, or 110 or ICAP=0 skip to 3.3.84 3.3.65

3.3.83 C13C3P (This line is read only if IPERM=7 and IC13P=001, 101, 011, or 111)
C13C3P- "C_1" coefficient for gaseous phase in three-phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 010, 001, or 011 skip to 3.3.86

3.3.84 C21W3P (This line is read only if IPERM=7 and IC23P=100, 101, 110, or 111)
C21W3P- "C_2" coefficient for aqueous phase in three-phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 010, 001, or 011 or ICAP=0 skip to 3.3.86

3.3.85 C21C3P (This line is read only if IPERM=7 and IC23P=100, 101, 110, or 111 and ICAP≠0)
C21C3P- "C_2" coefficient for aqueous phase in three-phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 100, 001, or 101 skip to 3.3.88

3.3.86 C22W3P (This line is read only if IPERM=7 and IC23P=010, 110, 011, or 111)
C22W3P- "C_2" coefficient for oleic phase in three-phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 100, 001, or 101 or ICAP=0 skip to 3.3.88

3.3.87 C22C3P **(This line is read only if IPERM=7 and IC23P=010, 110, 011, or 111 and ICAP≠0)**
C22C3P- "C_2" coefficient for oleic phase in three-phase flow at high trapping number for

all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 100, 010, or 110 skip to 3.3.90

3.3.88 C23W3P **(This line is read only if IPERM=7 and IC23P=001, 101, 011, or 111)**
C23W3P- "C_2" coefficient for gaseous phase in three-phase flow at low trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If IC23P=0, 100, 010, or 110 or ICAP=0 skip to 3.3.90

3.3.89 C23C3P **(This line is read only if IPERM=7 and IC23P=001, 101, 011, or 111)**
C23C3P- "C_2" coefficient for gaseous phase in three-phase flow at high trapping number for all grid blocks or I^{th} grid block
Example value: 1.0

If ICAP=0, skip to 3.3.91

3.3.90 T11, T12, T21, T22, T31, T32 **(This line is read only if ICAP ≠ 0)**
T11 - 1st Capillary desaturation curve parameter for aqueous phase
Example Value: 250
T12 - 2^{nd} Capillary desaturation curve parameter for aqueous phase
Example Value: 1.0
T21 - 1^{st} Capillary desaturation curve parameter for oleic phase
Example Value: 3000
T22 - 2^{nd} Capillary desaturation curve parameter for oleic phase
Example Value: 1.0
T31 - 1^{st} Capillary desaturation curve parameter for gaseous phase
Example Value: 25000
T32 - 2^{nd} Capillary desaturation curve parameter for gaseous phase
Example Value: 1.0

Hysteresis Model

The hysteresis options could be applied to any relative permeability model. From the available models in the DOECO2, however, the hysteresis is applied to only three relative permeability models: Corey, modified Jerauld's, and UTKR3P model. The following tables summarize the hysteresis models and their applicability for different wettability conditions. Note that the user needs to input the hysteresis model for different phase to comply with the combined three digits for hysteresis model as indicated in table 3. Otherwise, the code stops working with an error message.

Note: When UTKR3P relative permeability model is applied, it inherits a hysteresis model to reproduce the relative permeability curves for increasing and decreasing saturation processes. However, this

hysteresis model can be turned off with IHYST=0. Besides, other hysteresis models, i.e. Carlson, Larsen and Skauge, and UTHYST models, could be applied when IHYST=1. The following table shows Hysteresis models and their applicability.

Hysteresis Models	IHYSTPH	Applicability			IPERM (*)	Comment
		Water	Oil	Gas		
Default Hysteresis in UTKR3P (2012)	-1	YES	YES	YES	7	Inherent hysteresis model is applied
No Hysteresis	0	YES	YES	YES	all rel. perm models	No hysteresis is applied
Carlson (1981)	1	YES	YES	YES	3, 4, 6, and 7 (**)	Intermediate- and Non-wetting phases hysteresis
Fayers (1989)	2	NO	YES	NO	7	Oleic phase hysteresis when hysteresis is also applied to gaseous phase
Larsen and Skauge (1998)	3	YES	NO	YES	3, 4, and 7	Water as wetting phase and gas as non-wetting phase
UTHYST (2012)	4	YES	YES	YES	7	Intermediate- and non-wetting hysteresis

(*) IPERM to which the hysteresis model is applied
(**) For the Jerauld relative permeability model (IPERM=6), the Carlson hysteresis model (IHYST=1) is applied just to the gaseous phase.

The following table shows the Summary of hysteresis options with respect to the phase wettability.

Hysteretic Phase	Hysteresis Model* (Water/Oil/Gas)	Phase Wettability**			Comment
		Water	Oil	Gas	
Gas	001, 003, 004	W / I	W / I	N	
Oil	010, 040	W	I	N.A.	2-Phase Water-Oil
Water	100	I	W	N.A.	2-Phase Water-Oil
Gas + Water	101, 104, 401, 403, 404	I	W	N	No Hyst. For wetting phase
Gas + Oil	021, 023, 024	W	I	N	No Hyst. For wetting phase

Water + Oil + Gas (1)	311, 313, 314, 321, 323, 324, 341, 343, 344	W	I	N	Only IHYST=3 applies hyst. to water as wetting phase
Water + Oil + Gas (2)	121, 123, 124, 421,423,424	I	W	N	Only IHYST=2 applies hyst. to oil as wetting phase
* Three-digit combined hysteresis models with respect to IHYSTPH for each phase ** W= Wetting , I= Intermediate-wet, N= Non-wet, N.A.= Not applicable					

If IHYST=0 skip to 3.3.99

3.3.91 IHYSTPH1, IHYSTPH2, IHYSTPH3

IHYSTPH1- Indicates the hysteresis model for the aqueous phase

Possible Values:

-1: Default hysteresis in UTKR3P model is applied (if IPERM=7)
0: No hysteresis in the relative permeability
1: Carlson hysteresis model will be applied to the aqueous phase
3: Larsen and Skauge hysteresis model will be applied to the aqueous phase
4: UTHYST hysteresis model will be applied to the aqueous phase

IHYSTPH2- Indicates the hysteresis model for the oleic phase

Possible Values:

-1: Default hysteresis in UTKR3P model is applied (if IPERM=7)
0: No hysteresis in the relative permeability
1: Carlson hysteresis model will be applied to the oleic phase
2: Fayers hysteresis model will be applied to the oleic phase
4: UTHYST hysteresis model will be applied to the oleic phase

IHYSTPH3- Indicates the hysteresis model for the gaseous phase

Possible Values:

-1: Default hysteresis in UTKR3P model is applied (if IPERM=7)
0: No hysteresis in the relative permeability
1: Carlson hysteresis model will be applied to the gaseous phase
2: Fayers hysteresis model will be applied to the gaseous phase
3: Larsen and Skauge hysteresis model will be applied to the gaseous phase
4: UTHYST hysteresis model will be applied to the gaseous phase

Note: UTKR3P relative permeability model has an inherent hysteresis model applicable to different phases (IHYSTPH=-1). But this behavior could be changed by selecting proper IHYSTPH for the phase(s), e.g. IHYSTPH= 0, 1, 2, 3, or 4.

Carlson's model (1981): Hysteresis in the saturation direction will be applied to the intermediate- and/or non-wetting phase(s) so that the relative permeability of the primary increasing and the primary decreasing phase saturation processes are different. The secondary drainage relative permeability, however, follows the primary imbibition relative permeability.

Fayers model (1989): oil residua saturation decreases according to the gas trapped saturation due to the hysteresis for the gas phase.

Larsen and Skauge model (1998): cycle dependent hysteresis (saturation direction and saturation path hysteresis) in phase relative permeability of water as wetting phase and gas as the non-wetting phase.
UT hysteresis model (2012): cycle dependent hysteresis (saturation direction and saturation path hysteresis) in phase relative permeability for all phases.

3.3.92 SATTOLHYST, ILAND
SATTOLHYST- Level of acceptable tolerance for the saturation change without considering it as a saturation history change
Example value: 0.001
ILAND- Land coefficient for different phases input method for different phases
Possible values:
0: Land coefficient is calculated
1: Land coefficient is set by user

If ILAND=0 skip to 3.3.94

3.3.93 CLAND1, CLAND2, CLAND3
CLAND1 – "L1" for aqueous phase for all grid blocks or I^{th} grid block (see note)
Example value: 2.0
CLAND2 - "L_2" for oleic phase for all grid blocks or I^{th} grid block (see note)
Example value: 2.0
CLAND3 - "L_3" for gaseous phase for all grid blocks or I^{th} grid block (see note)
Example value: 2.0
Note: In UTHYST model, the Land coefficient is variable and updated dynamically. As a result, the entered values are omitted.
If IRPERM=0 (values are constant), only one value for each of the residual saturations is required by the program.
If IRPERM=1 (values vary in the Z-direction), NZ values are required by the program because the residual saturations for each grid block in the Z-direction must be specified.
If IRPERM>1 (values vary for each grid block), NB values are required in order to define the residual saturations for each grid block.

3.3.94 HYSTB1, HYSTB2, HYSTB3
HYSTB1 - "β1" parameter for aqueous phase
Example value: 0.0
HYSTB2 - "β_2" parameter for oleic phase
Example value: 0.0
HYSTB3 - "β_3" parameter for gaseous phase
Example value: 0.0
Note: "β" parameter is bounded: $0 \leq \beta \leq 1$

If IHYSTPH1 and IHYSTPH2 ≠ 4 OR IHYSTPH3 ≠ 3 or 4 skip to 3.3.97

3.3.95 HHYSTA1, HYSTA2, HYSTA3
HYSTA1 - "α1" parameter for aqueous phase in UTHYST model

Example value: 1.0

HYSTA2 - "α_2" parameter for oleic phase in UTHYST model
Example value: 1.0

HYSTA3 - "α_3" parameter for gaseous phase in UTHYST model or in Larsen and Skauge model
Example value: 1.0

(This line is read only if IHYSTPH1=3 or 4 and IHYSTPH=100, 101, 110, or 111)
Note: if this lines is read and IHYSTPH for specific phase(s) does not meet the required conditions, the code ignores the input value

If IHYSTPH1 ≠ 3 skip to 3.3.98

3.3.96 PR12P3P
PR12P3P: Water endpoint relative permeability ratio at two-phase to three-phase flow
Example: 2.25

If IPERM ≤ 5

E12P3P: Water Corey exponent ratio at two-phase to three-phase flow

If IPERM = 7 and IC13P=0, 010, 001, or 011

C12P3P: Water relative permeability curvature 'C1' ratio at two-phase to three-phase flow

If IPERM = 7 and IC23P=0, 010, 001, or 011

C22P3P: Water relative permeability curvature 'C2' ratio at two-phase to three-phase flow

If IHYSTPH2 ≠ 2 skip to 3.3.98

3.3.97 HYSTWET2
HYSTWET2: "a_o" wetting parameter for oleic phase
Example value: 0.5
Note: "a_o" parameter is bounded: $0 \leq a_o \leq 1$

If IPERM=7 skip to 3.3.99

3.3.98 S1C, S2C, and S3C (This line is read only if IPERM≠7 and0 IHYST=1, 2, or 3)
S1C- Connate water saturation
Example value: 0.0
S2C- Critical oil saturation
Example value: 0.0
S3C- Critical gas saturation
Example value: 0.0
Note: For IPERM=7, these parameters were set in the relative permeability parameters

Section

3.3.99 IPRESS, IPREC, METHSL, OMEGA

IPRESS - Flag indicating which pressure solver is to be used.

Possible Values:

Direct solvers:

1 : Thomas algorithm is to be used

2 : Banded Gaussian elimination is to be used

Iterative solvers:

3 : Biconjugate gradient algorithm is to be used

4 : Biconjugate gradient squared algorithm is to be used

Note: The above solvers work for correct grids or face punch-out. For collapsed gridblock BICGS is used. If there is collapsed gridblock in corner point option, IPRESS should be 1 to use BICGS.

IPREC - Flag indicating which preconditioner is to be used with the iterative solvers.

Possible Values:

1 : Richardson is to be used (null, i.e. no preconditioner)

2 : Jacobi preconditioner is to be used

3 : Incomplete Cholesky (IC) is to be used

4 : Modified incomplete Cholesky (MIC) is to be used

METHSL - Flag indicating which solution method is to be used with the IC and MIC preconditioners.

Possible Values:

1 : Block method (using all FORTRAN) is to be used

2 : Block method (using FOLRP) is to be used

3 : Wave method on planes is to be used

OMEGA - Modification factor to be used with the MIC preconditioner

Possible Values:

0.0 : No modification will be used (same as selecting IC)

1.0 : Full modification will be used

0.0 < OMEGA < 1.0: Partial modification will be used

Note: The Thomas algorithm is recommended for 1-D simulations. The banded Gaussian elimination method can be used for 2-D simulations involving small numbers of grid blocks. For 2-D simulations involving large numbers of grid blocks and 3-D simulations, it is recommended that one of the biconjugate gradient algorithms be used.

If the Thomas method or iterative solvers are used, set the NBWM parameter to 7. If Gaussian elimination is used, set the NBWM parameter to the actual bandwidth or 7, whichever is greater. NS1M for the above solvers must be set to 1.

3.3.100 ITMAX, LEVLIT, IDGTS, NS1, NS2, ZETAIT

ITMAX - Maximum number of iterations allowed for iterative pressure solvers.

LEVLIT - Flag indicating the level of output detail to be printed to the default output file.

Possible Values:

-1 : Do not print anything to the default output file
0 : Print only fatal error messages to the default output file
1 : Print warning messages and minimum output information to the default output file
2 : Print a moderate summary to the default output file
3 : Print the parameter values for every iteration and informative comments to the default output file
4 : Print an approximate solution after every iteration to the default output file

Note: For interactive jobs, this data is sent to the terminal and for batch jobs, the data is sent to the run log file.

IDGTS - Flag indicating whether error analysis should be performed for the iterative pressure solvers.

Possible Values:

-1 : Do not perform error analysis
0 : Compute digits of accuracy (DIGIT1 and DIGIT2) and store in RPARM array
1 : Print DIGIT1 and DIGIT2 to the default output file (see note above)

NS1 - This variable is currently not used in DOECO2. It is anticipated that this value will be used in a future version of the program.

NS2 - This variable is currently not used in DOECO2. It is anticipated that this value will be used in a future version of the program.

ZETAIT - Tolerance used for iterative solvers.

Example Value: 10^{-10}

Note: These values are only used by the program when IPRESS=3 or 4

3.3.101 NREGION **(This line is read only if IRTYPE=1)**

NREGION - Number of regions used to specify relative permeability and capillary pressure when the rock type option is used.

Note: Each gridblock falls within one of the regions specified by NREGION. The region numbers for each gridblock are specified in the PVTNUM input file. The user must specify at least 2 regions.

3.3.102 S1RW(I), S2RW1(I), S2RW2(I), S3RW(I), S4RW1(I), S4RW2(I), for I=1, NREGION **(This line is read only if IRTYPE=1)**

S1RW(I) - Water residual saturation for water-liquid hydrocarbon flow at low capillary number for all gridblocks in the I^{th} region.

Units: fraction

S2RW1(I) - Oil residual saturation for water-oil flow at low capillary number for all gridblocks in the I^{th} region.

Units: fraction

S2RW2(I) - Oil residual saturation for gas-oil flow at low capillary number for all gridblocks in the I^{th} region.

Units: fraction

S3RW(I)- Gas residual saturation for gas-liquid hydrocarbon flow at low capillary number for all gridblocks in the I^{th} region.

Units: fraction

S4RW1(I)- Second liquid residual saturation for water-second liquid flow at low capillary number for all gridblocks in the I^{th} region.

Units: fraction

S4RW2(I)- Second liquid residual saturation for gas-second liquid flow at low capillary number for all gridblocks in the I^{th} region

3.3.103 S1RC(I), S2RC1(I), S2RC2(I), S3RC(I), S4RC1(I), S4RC2(I), for I=1, NREGION **(This line is read only if IRTYPE=1 and ICAP#0)**

S1RC(I) - Water residual saturation for water-liquid hydrocarbon flow at high capillary number for all gridblocks in the I^{th} region.

Units: fraction

S2RC1(I) - Oil residual saturation for water-oil flow at high capillary number for all gridblocks in the I^{th} region.

Units: fraction

S2RC2(I) - Oil residual saturation for gas-oil flow at high capillary number for all gridblocks in the I^{th} region.

Units: fraction

S3RC(I)- Gas residual saturation for gas-liquid hydrocarbon flow at high capillary number for all gridblocks in the I_{th} region.

Units: fraction

S4RC1(I)- Second liquid residual saturation for water-second liquid flow at high capillary number for all gridblocks in the I^{th} region.

Units: fraction

S4RC2(I)- Second liquid residual saturation for gas-second liquid flow at high capillary number for all gridblocks in the I^{th} region.

Units: fraction

3.3.104 P1RW(I), P2RW(I), P3RW(I), P4RW(I), for I=1, NREGION **(This line is read only if IRTYPE=1)**

P1RW(I) - End point water relative permeability at low capillary number for all gridblocks.

P2RW(I) - End point oil relative permeability at low capillary number for all gridblocks in the I^{th} region.

P3RW(I) - End point gas relative permeability at low capillary number for all gridblocks in the I^{th} region.

P4RW(I) - End point second hydrocarbon liquid relative permeability at low capillary number for all gridblocks in the I^{th} region.

3.3.105 P1RC(I), P2RC(I), P3RC(I), P4RC(I), for I=1, NREGION **(This line is read only if IRTYPE=1 and ICAP#0)**

P1RC(I) - End point water relative permeability at high capillary number for all gridblocks.

P2RC(I) - End point oil relative permeability at high capillary number for all gridblocks in the I^{th} region.

P3RC(I) - End point gas relative permeability at high capillary number for all gridblocks in the I^{th} region.

P4RC(I) - End point second hydrocarbon liquid relative permeability at high capillary number for all gridblocks in the I_{th} region.

3.3.106 E1W(I), E2W1(I), E2W2(I), E3W(I), E4W1(I), E4W2(I), for I=1, NREGION **(This line is read only if IRTYPE=1)**

E1W(I) - Exponent of water relative permeability for water-liquid hydrocarbon flow at low capillary number for all gridblocks in the I^{th} region.

E2W1(I) - Exponent of oil relative permeability for water-oil flow at low capillary number for all gridblocks in the I^{th} region.

E2W2(I) - Exponent of oil relative permeability for gas-oil flow at low capillary number for all gridblocks in the I^{th} region.

E3W(I) - Exponent of gas relative permeability for gas-liquid hydrocarbon flow at low capillary number for all gridblocks in the I^{th} region.

E4W1(I) - Exponent of second liquid relative permeability for water-second liquid flow at low capillary number for all gridblocks in the I^{th} region.

ERW2(I) - Exponent of second liquid relative permeability for gas-second liquid flow at low capillary number for all gridblocks in the I^{th} region.

3.3.107 E1C(I), E2C1(I), E2C2(I), E3C(I), E4C1(I), E4C2(I), for I=1, NREGION **(This line is read only if IRTYPE=1 and ICAP#0)**

E1C(I) - Exponent of water relative permeability for water-liquid hydrocarbon flow at high capillary number for all gridblocks in the I_{th} region.

E2C1(I) - Exponent of oil relative permeability for water-oil flow at high capillary number for all gridblocks in the I_{th} region.

E2C2(I) - Exponent of oil relative permeability for gas-oil flow at high capillary number for all gridblocks in the I_{th} region.

E3C(I) - Exponent of gas relative permeability for gas-liquid hydrocarbon flow at high capillary number for all gridblocks in the I_{th} region.

E4C1(I) - Exponent of second liquid relative permeability for water-second liquid flow at high capillary number for all gridblocks in the I_{th} region.

ERC2(I) - Exponent of second liquid relative permeability for gas-second liquid flow at high capillary number for all gridblocks in the I_{th} region.

3.4 Initial Conditions

This section of the input specifies the initial conditions and is read by subroutine INICON.F. Three comment lines precede each data line.

3.4.0 Comment Lines
There are no additional comment lines at the beginning of this section

3.4.1 T (This line is read only if ISTART=1)
T - Initial time of the simulation run.
Units: days

3.4.2 MP (This line is read only if ISTART>1)
MP - Flag indicating whether the initial pressure is constant or variable.
Possible Values:
0 : The initial pressure is constant
1 : The initial pressure is variable
2 : Initial pressure for each gridblock is read from PRES input file

3.4.3 P << or >>
P(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if ISTART>1)
P or P(I) - Initial pressures of all grid blocks or I^{th} grid block (see note).
Units: psi

Note: If MP=0 (the initial pressures are constant), only one value is required by the program.
If MP=1 (the initial pressures are variable), NB values for P(I) are required by the program where P(I) is the initial pressure of the I^{th} grid block. MP =2 is the same as MP =1 but Initial pressure for each gridblock is read from PRES input file.

3.4.4 MSAT (This line is read only if ISTART>1)
MSAT - Flag indicating whether the initial water saturation is constant or variable.
Possible Values:
0 : The initial water saturation is constant
1 : The initial water saturation is variable
2 : Initial water saturation for each gridblock is read from WSAT input file

3.4.5 SAT << or >>
SAT(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if ISTART>1)
SAT or SAT(I) - Initial water saturations (fraction) of all grid blocks or I^{th} grid block (see note).
Units: dimensionless

Note: If MSAT=0 (the initial water saturations are constant), only one value is required by the program.
If MSAT=1 (the initial water saturations are variable), NB values for SAT(I) are

required by the program where SAT(I) is the initial water saturation of the I^{th} grid block. MSAT =2 is the same as MSAT =1 but Initial pressure for each gridblock is read from WSAT input file.

3.4.6 MOMFR (This line is read only if ISTART>1)

MOMFR - Flag indicating whether initial overall composition is constant or variable.

Possible Values:

0 : The initial overall composition is constant

1 : The initial overall composition is variable

2 : Initial overall composition for each gridblock is read from MOLFR input file

3.4.7 OMFR(K), for K=1, NC << or >>

OMFR(I,K), for K=1, NC, for I=1, NB where NB=NX × NY × NZ

(This line is read only if ISTART>1)

OMFR(K) or OMFR(I,K) - Initial overall hydrocarbon mole fraction of K^{th} component for all grid blocks or for I^{th} grid block (see note).

Units: dimensionless

Note: If MOMFR=0 (the initial overall hydrocarbon mole fractions are constant), NC values are required by the program. These values are the overall hydrocarbon compositions of each component in the order specified on input line 3.1.3

If MOMFR=1 (the initial overall compositions are variable), NB × NC values are required by the program. These values are the overall hydrocarbon mole fractions of each component for each grid block. MOMFR=2, but Initial overall composition for each gridblock is read from MOLFR input file.

3.5 Tracer Initial Concentrations

This section of the input specifies the initial concentrations. Three comment lines precede each data line.

3.5.0 Comment Lines
There are no additional comment lines at the beginning of this section

3.5.1 NCINT (This line is read only if IFLAGT=1)
NCINT - Number of tracers initially present in the reservoir.

3.5.2 Input lines 3.6.2.a and 3.6.2.b are used to specify the initial tracer concentrations. The lines are repeated NCINT times, once for each tracer.

3.5.2.a NTR, MCINT (This line is read only if NCINT>0)
NTR - Tracer number.
MCIN - Flag indicating whether the initial concentration for the NTR^{th} tracer is constant or variable.
Possible Values:
0 : Initial concentration for NTR^{th} tracer is constant
1 : Initial concentration for NTR^{th} tracer is variable

3.5.2.b TNKT <<or>>
TNKT(I), for I=1, NB where NB=NX × NY × NZ (This line is read only if NCINT>0)
TNKT or TNKT(I) - Initial concentration for NTR^{th} tracer.
Units: as specified by IUNIT(I) on input line 3.1.23

Note: If MCIN=0 (the initial concentrations are constant), only one value is required by the program.
If MCIN=1 (the initial concentrations are variable), NB values for TNKT(I) are required by the program where TNKT(I) is the initial tracer concentration of the I^{th} grid block.

3.6 Poroelasticity Model Input

This section consists of poroelasticity model input data. Recall that there are seven comment lines at the beginning of this section and that each data line is preceded by three comment lines.

3.6.1 POROEON

POROEON – Poroelasticity model option.

Possible Values:

0: Simulation without poroelasticity model, no further input for poroelasticity model.

1: Simulation with poroelasticity model, further input for poroelasticity model required.

3.6.2 MPREDISP(I), for I = 1, NPR

MPREDISP(I) – Flag indicating whether poroelasticity model displacement (interpolated at cell center) will be printed to file TABLE at I^{th} printing interval.

Possible Values:

0: Do not print displacement values.

1: Print displacement values.

3.6.3 MPRESTRS(I), for I = 1, NPR

MPRESTRS(I) – Flag indicating whether poroelasticity model stresses (interpolated at cell center) will be printed to file TABLE at I^{th} printing interval.

Possible Values:

0: Do not print stress values.

1: Print stress values.

3.6.4 DISPUNIT

DISPUNIT – Option to choose unit for displacement output in S3GRAF.

Possible Values:

1: Unit for displacement output in S3GRAF is [inch].

2: Unit for displacement output in S3GRAF is [foot].

3.6.5 PESOLVER

PESOLVER – Solver option for poroelasticity model.

Possible Values:

1: Preconditioned restarted GMRES solver.

2: HYPRE AMG solver.

3.6.6 PEGMRESMAX_IT, PEGMRESMR, PEGMRESTOL_ABS, PEGMRESTOL_REL

This option is required ONLY if PESOLVER=1

PEGMRESMAX_IT – Max number of outer iterations for preconditioned restarted GMRES solver.

PEGMRESMR – Max number of inner iterations for preconditioned restarted GMRES solver.

PEGMRESTOL_ABS – Absolute error tolerance.

PEGMRESTOL_REL – Relative error tolerance.

3.6.7 HYPREID, HYPRETOL, HYPREMAXIT

This option is required ONLY if PESOLVER=2

HYPREID – Solver and preconditioner option in HYPRE library for poroelasticity model.
Possible Values:
0: AMG as the solver.
1: AMG as the preconditioner with PCG as the solver.
2: AMG as the preconditioner with GMRES as the solver.
HYPRETOL – Tolerance for linear solver for poroelasticity model.
Example Value: 1.E-12
HYPREMAXIT – Maximum number of iterations for linear solver.

3.6.8 ITYPE_ BOUNDARY(I,J)
ITYPRE_BOUNDARY – Type of boundary condition on boundary face I and direction J. User should specify all three directions on a face first, and then continue to the next face. The ordering of boundary faces is as follows:
1: Low Y face
2: High Y face
3: Low Z face
4: High Z face
5: Low X face
6: High X face
And the ordering of direction is as follows:
1: X direction
2: Y direction
3: Z direction
Possible Values for ITYPE_BOUNDARY(I,J):
1: Dirichlet boundary condition (user-specified displacement) on face I in direction J
2: Neumann boundary condition (user-specified traction) on face I in direction J

3.6.9 MBCYX
MBCYX – Flag indicating whether the boundary condition data are constant on low Y face in X direction.
Possible Values:
0: The boundary condition data are constant on low Y face in X direction
1: The boundary condition data are variable on low Y face in X direction

3.6.10 EBCON(1,1) <<or>> EBCON(I,1,1) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(1,1) = 1 <<or>>EBCON(I,1,1) for I = 1, NX * NZ if ITYPE_BOUNDARY(1,1) = 2 EBCON(1,1) or EBCON(I,1,1) – Boundary condition data on low Y face in X direction. Data values are positive if along the positive axis direction.
Note: If MBCYX = 0 (the boundary condition data are constant on low Y face in X direction), only one value is required by the program.
If MBCYX = 1 (the boundary condition data are variable on low Y face in X direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(1,1) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(1,1) = 2). Boundary condition needs to be input in the order such that Z

direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.11 MBCYY

MBCYY – Flag indicating whether the boundary condition data are constant on low Y face in Y direction.

Possible Values:

0: The boundary condition data are constant on low Y face in Y direction

1: The boundary condition data are variable on low Y face in Y direction

3.6.12 EBCON(2,1) <<or>>

EBCON(I,2,1) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(1,2) = 1 <<or>>

EBCON(I,2,1) for I = 1, NX * NZ if ITYPE_BOUNDARY(1,2) = 2

EBCON(2,1) or EBCON(I,2,1) – Boundary condition data on low Y face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCYY = 0 (the boundary condition data are constant on low Y face in Y direction), only one value is required by the program.

If MBCYY = 1 (the boundary condition data are variable on low Y face in Y direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(1,2) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(1,2) = 2). Boundary condition needs to be input in the order such that Z direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.13 MBCYZ

MBCYZ – Flag indicating whether the boundary condition data are constant on low Y face in Z direction.

Possible Values:

0: The boundary condition data are constant on low Y face in Z direction

1: The boundary condition data are variable on low Y face in Z direction

3.6.14 EBCON(3,1) <<or>>

EBCON(I,3,1) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(1,3) = 1 <<or>>

EBCON(I,3,1) for I = 1, NX * NZ if ITYPE_BOUNDARY(1,3) = 2

EBCON(3,1) or EBCON(I,3,1) – Boundary condition data on low Y face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCYZ = 0 (the boundary condition data are constant on low Y face in Z direction), only one value is required by the program.

If MBCYZ = 1 (the boundary condition data are variable on low Y face in Z direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(1,3) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(1,3) = 2). Boundary condition needs to be input in the order such that Z direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.15 MBCYPX

MBCYPX – Flag indicating whether the boundary condition data are constant on high Y face in X direction.

Possible Values:

0: The boundary condition data are constant on high Y face in X direction

1: The boundary condition data are variable on high Y face in X direction

3.6.16 EBCON (1, 2) <<or>>

EBCON (I, 1, 2) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(2,1) = 1 <<or>>

EBCON (I, 1, 2) for I = 1, NX * NZ if ITYPE_BOUNDARY(2,1) = 2

EBCON (1, 2) or EBCON (I, 1, 2) – Boundary condition data on high Y face in X direction. Data values are positive if along the positive axis direction.

Note: If MBCYPX = 0 (the boundary condition data are constant on high Y face in X direction), only one value is required by the program.

If MBCYPX = 1 (the boundary condition data are variable on high Y face in X direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(2,1) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(2,1) = 2). Boundary condition needs to be input in the order such that Z direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.17 MBCYPY

MBCYPX – Flag indicating whether the boundary condition data are constant on high Y face in Y direction.

Possible Values:

0: The boundary condition data are constant on high Y face in Y direction

1: The boundary condition data are variable on high Y face in Y direction

3.6.18 EBCON(2,2) <<or>>

EBCON(I,2,2) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(2,2) = 1 <<or>>

EBCON(I,2,2) for I = 1, NX * NZ if ITYPE_BOUNDARY(2,2) = 2

EBCON(2,2) or EBCON(I,2,2) – Boundary condition data on high Y face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCYPY = 0 (the boundary condition data are constant on high Y face in Y direction), only one value is required by the program.

If MBCYPY = 1 (the boundary condition data are variable on high Y face in Y direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(2,2) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(2,2) = 2). Boundary condition needs to be input in the order such that Z direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.19 MBCYPZ

MBCYPZ – Flag indicating whether the boundary condition data are constant on high Y face in Z direction.

Possible Values:

0: The boundary condition data are constant on high Y face in Z direction
1: The boundary condition data are variable on high Y face in Z direction

3.6.20 EBCON(3,2) <<or>>

EBCON(I,3,2) for I = 1, (NX+1) * (NZ+1) if ITYPE_BOUNDARY(2,3) = 1 <<or>>
EBCON(I,3,2) for I = 1, NX * NZ if ITYPE_BOUNDARY(2,3) = 2
EBCON(3,2) or EBCON(I,3,2) – Boundary condition data on high Y face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCYPZ = 0 (the boundary condition data are constant on high Y face in Z direction), only one value is required by the program.
If MBCYPZ = 1 (the boundary condition data are variable on high Y face in Z direction), (NX+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(2,3) = 1) whereas NX*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(2,3) = 2). Boundary condition needs to be input in the order such that Z direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Z direction.

3.6.21 MBCZX

MBCZX – Flag indicating whether the boundary condition data are constant on low Z face in X direction.

Possible Values:

0: The boundary condition data are constant on low Z face in X direction
1: The boundary condition data are variable on low Z face in X direction

3.6.22 EBCON(1,3) <<or>>

EBCON(I,1,3) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(3,1) = 1 <<or>>
EBCON(I,1,3) for I = 1, NX * NY if ITYPE_BOUNDARY(3,1) = 2
EBCON(1,3) or EBCON(I,1,3) – Boundary condition data on low Z face in X direction. Data values are positive if along the positive axis direction.

Note: If MBCZX = 0 (the boundary condition data are constant on low Z face in X direction), only one value is required by the program.
If MBCZX = 1 (the boundary condition data are variable on low Z face in X direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(3,1) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(3,1) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.23 MBCZY

MBCZY – Flag indicating whether the boundary condition data are constant on low Z face in Y direction.

Possible Values:

0: The boundary condition data are constant on low Z face in Y direction
1: The boundary condition data are variable on low Z face in Y direction

3.6.24 EBCON(2,3) <<or>>

EBCON(I,2,3) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(3,2) = 1 <<or>>
EBCON(I,2,3) for I = 1, NX * NY if ITYPE_BOUNDARY(3,2) = 2
EBCON(2,3) or EBCON(I,2,3) – Boundary condition data on low Z face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCZY = 0 (the boundary condition data are constant on low Z face in Y direction), only one value is required by the program.
If MBCZY = 1 (the boundary condition data are variable on low Z face in Y direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(3,2) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(3,2) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.25 MBCZZ

MBCZY – Flag indicating whether the boundary condition data are constant on low Z face in Z direction.

Possible Values:

0: The boundary condition data are constant on low Z face in Z direction
1: The boundary condition data are variable on low Z face in Z direction

3.6.26 EBCON(3,3) <<or>>

EBCON(I,3,3) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(3,3) = 1 <<or>>
EBCON(I,3,3) for I = 1, NX * NY if ITYPE_BOUNDARY(3,3) = 2
EBCON(3,3) or EBCON(I,3,3) – Boundary condition data on low Z face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCZZ = 0 (the boundary condition data are constant on low Z face in Z direction), only one value is required by the program.
If MBCZZ = 1 (the boundary condition data are variable on low Z face in Z direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(3,3) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(3,3) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.27 MBCZPX

MBCZPX – Flag indicating whether the boundary condition data are constant on high Z face in X direction.

Possible Values:

0: The boundary condition data are constant on high Z face in X direction
1: The boundary condition data are variable on high Z face in X direction

3.6.28 EBCON(1,4) <<or>>

EBCON(I,1,4) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(4,1) = 1 <<or>>

EBCON(I,1,4) for I = 1, NX * NY if ITYPE_BOUNDARY(4,1) = 2

EBCON(1,4) or EBCON(I,1,4) – Boundary condition data on high Z face in X direction. Data values are positive if along the positive axis direction.

Note: If MBCZPX = 0 (the boundary condition data are constant on high Z face in X direction), only one value is required by the program.

If MBCZPX = 1 (the boundary condition data are variable on high Z face in X direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(4,1) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(4,1) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.29 MBCZPY

MBCZPY – Flag indicating whether the boundary condition data are constant on high Z face in Y direction.

Possible Values:

0: The boundary condition data are constant on high Z face in Y direction

1: The boundary condition data are variable on high Z face in Y direction

3.6.30 EBCON(2,4) <<or>>

EBCON(I,2,4) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(4,2) = 1 <<or>>

EBCON(I,2,4) for I = 1, NX * NY if ITYPE_BOUNDARY(4,2) = 2

EBCON(2,4) or EBCON(I,2,4) – Boundary condition data on high Z face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCZPY = 0 (the boundary condition data are constant on high Z face in Y direction), only one value is required by the program.

If MBCZPY = 1 (the boundary condition data are variable on high Z face in Y direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(4,2) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(4,2) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.31 MBCZPZ

MBCZPZ – Flag indicating whether the boundary condition data are constant on high Z face in Z direction.

Possible Values:

0: The boundary condition data are constant on high Z face in Z direction

1: The boundary condition data are variable on high Z face in Z direction

3.6.32 EBCON(3,4) <<or>>

EBCON(I,3,4) for I = 1, (NX+1) * (NY+1) if ITYPE_BOUNDARY(4,3) = 1 <<or>>

EBCON(I,3,4) for I = 1, NX * NY if ITYPE_BOUNDARY(4,3) = 2

EBCON(3,4) or EBCON(I,3,4) – Boundary condition data on high Z face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCZPZ = 0 (the boundary condition data are constant on high Z face in Z direction), only one value is required by the program.

If MBCZPZ = 1 (the boundary condition data are variable on high Z face in Z direction), (NX+1)*(NY+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(4,3) = 1) whereas NX*NY values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(4,3) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than X direction when IXYZ = 0. When IXYZ = 1, X is the faster changing direction than Y direction.

3.6.33 MBCXX

MBCXX – Flag indicating whether the boundary condition data are constant on low X face in X direction.

Possible Values:

0: The boundary condition data are constant on low X face in X direction

1: The boundary condition data are variable on low X face in X direction

3.6.34 EBCON(1,5) <<or>>

EBCON(I,1,5) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(5,1) = 1 <<or>>
EBCON(I,1,5) for I = 1, NY * NZ if ITYPE_BOUNDARY(5,1) = 2

EBCON(1,5) or EBCON(I,1,5) – Boundary condition data on low X face in X direction. Data values are positive if along the positive axis direction.

Note: If MBCXX = 0 (the boundary condition data are constant on low X face in X direction), only one value is required by the program.

If MBCXX = 1 (the boundary condition data are variable on low X face in X direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(5,1) = 1) whereas NY*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(5,1) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.35 MBCXY

MBCXY – Flag indicating whether the boundary condition data are constant on low X face in Y direction.

Possible Values:

0: The boundary condition data are constant on low X face in Y direction

1: The boundary condition data are variable on low X face in Y direction

3.6.36 EBCON(2,5) <<or>>

EBCON(I,2,5) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(5,2) = 1 <<or>>
EBCON(I,2,5) for I = 1, NY * NZ if ITYPE_BOUNDARY(5,2) = 2

EBCON(2,5) or EBCON(I,2,5) – Boundary condition data on low X face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCXY = 0 (the boundary condition data are constant on low X face in Y direction), only one value is required by the program.
If MBCXY = 1 (the boundary condition data are variable on low X face in Y direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(5,2) = 1) whereas NY*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(5,2) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.37 MBCXZ

MBCXZ – Flag indicating whether the boundary condition data are constant on low X face in Z direction.

Possible Values:

0: The boundary condition data are constant on low X face in Z direction

1: The boundary condition data are variable on low X face in Z direction

3.6.38 EBCON(3,5) <<or>>

EBCON(I,3,5) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(5,3) = 1 <<or>>
EBCON(I,3,5) for I = 1, NY * NZ if ITYPE_BOUNDARY(5,3) = 2
EBCON(3,5) or EBCON(I,3,5) – Boundary condition data on low X face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCXZ = 0 (the boundary condition data are constant on low X face in Z direction), only one value is required by the program.
If MBCXZ = 1 (the boundary condition data are variable on low X face in Z direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(5,3) = 1) whereas NY*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(5,3) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.39 MBCXPX

MBCXPX – Flag indicating whether the boundary condition data are constant on high X face in X direction.

Possible Values:

0: The boundary condition data are constant on high X face in X direction

1: The boundary condition data are variable on high X face in X direction

3.6.40 EBCON(1,6) <<or>>

EBCON(I,1,6) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(6,1) = 1 <<or>>
EBCON(I,1,6) for I = 1, NY * NZ if ITYPE_BOUNDARY(6,1) = 2
EBCON(1,6) or EBCON(I,1,6) – Boundary condition data on high X face in X direction. Data values are positive if along the positive axis direction.

Note: If MBCXPX = 0 (the boundary condition data are constant on high X face in X direction), only one value is required by the program.
If MBCXPX = 1 (the boundary condition data are variable on high X face in X direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(6,1) = 1) whereas

NY*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(6,1) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.41 MBCXPY

MBCXPY – Flag indicating whether the boundary condition data are constant on high X face in Y direction.

Possible Values:

0: The boundary condition data are constant on high X face in Y direction

1: The boundary condition data are variable on high X face in Y direction

3.6.42 EBCON(2,6) <<or>>

EBCON(I,2,6) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(6,2) = 1 <<or>>

EBCON(I,2,6) for I = 1, NY * NZ if ITYPE_BOUNDARY(6,2) = 2

EBCON(2,6) or EBCON(I,2,6) – Boundary condition data on high X face in Y direction. Data values are positive if along the positive axis direction.

Note: If MBCXPY = 0 (the boundary condition data are constant on high X face in Y direction), only one value is required by the program.

If MBCXPY = 1 (the boundary condition data are variable on high X face in Y direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(6,2) = 1) whereas NY*NZ values are required by the program for face based Neumann (traction) type boundary condition (ITYPE_BOUNDARY(6,2) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.43 MBCXPZ

MBCXPZ – Flag indicating whether the boundary condition data are constant on high X face in Z direction.

Possible Values:

0: The boundary condition data are constant on high X face in Z direction

1: The boundary condition data are variable on high X face in Z direction

3.6.44 EBCON(3,6) <<or>>

EBCON(I,3,6) for I = 1, (NY+1) * (NZ+1) if ITYPE_BOUNDARY(6,3) = 1 <<or>>

EBCON(I,3,6) for I = 1, NY * NZ if ITYPE_BOUNDARY(6,3) = 2

EBCON(3,6) or EBCON(I,3,6) – Boundary condition data on high X face in Z direction. Data values are positive if along the positive axis direction.

Note: If MBCXPZ = 0 (the boundary condition data are constant on high X face in Z direction), only one value is required by the program.

If MBCXPZ = 1 (the boundary condition data are variable on high X face in Z direction), (NY+1)*(NZ+1) values are required by the program for nodal based Dirichlet (displacement) type boundary condition (ITYPE_BOUNDARY(6,3) = 1) whereas NY*NZ values are required by the program for face based Neumann (traction) type

boundary condition (ITYPE_BOUNDARY(6,3) = 2). Boundary condition needs to be input in the order such that Y direction is the faster changing direction than Z direction when IXYZ = 0 and IXYZ = 1.

3.6.45 MMODUL

MMODUL – Flag indicating whether Young's moduli are constant.

Possible Values:

0: Young's moduli are constant for all grid elements.

1: Young's moduli are variable for grid elements.

3.6.46 EMODUL <<or>>

EMODUL(I), for I = 1, NB

EMODUL or EMODUL(I) – Young's moduli for each grid element. Unit: psi

Note: If MMODUL = 0 (Young's moduli are constant for all grid elements), only one value is required by the program.

If MMODUL = 1 (Young's moduli are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.47 MPOISS

MPOISS – Flag indicating whether Poisson's ratios are constant.

Possible Values:

0: Poisson's ratios are constant for all grid elements.

1: Poisson's ratios are variable for grid elements.

3.6.48 EPOISS <<or>>

EPOISS(I), for I = 1, NB

EPOISS or EPOISS(I) – Poisson's ratios for each grid element. Unit: dimensionless

Note: If MPOISS = 0 (Poisson's ratios are constant for all grid elements), only one value is required by the program.

If MPOISS = 1 (Poisson's ratios are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.49 MBIOTA

MBIOTA – Flag indicating whether Biot's constants are constant.

Possible Values:

0: Biot's constants are constant for all grid elements.

1: Biot's constants are variable for grid elements.

3.6.50 EBIOTA <<or>>

EBIOTA(I), for I = 1, NB

EBIOTA or EBIOTA(I) – Biot's constants for each grid element. Unit: dimensionless

Note: If MBIOTA = 0 (Biot's contants are constant for all grid elements), only one value is required by the program.

If MBIOTA = 1 (Biot's contants are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.51 MBIOTM

MBIOTM – Flag indicating whether the inverses of Biot's moduli are constant.

Possible Values:

0: The inverses of Biot's moduli are constant for all grid elements.

1: The inverses of Biot's moduli are variable for grid elements.

2: The inverses of Biot's moduli will be approximated from other input variables.

3.6.52 EBIOTM <<or>>

EBIOTM(I), for I = 1, NB

EBIOTM or EBIOTM(I) – The inverses of Biot's moduli for each grid element. Unit: dimensionless

Note: If MBIOTM = 0 (the inverses of Biot's constants are constant for all grid elements), only one value is required by the program.

If MBIOTM = 1 (the inverses of Biot's constants are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

If MBIOTM = 2 (the inverses of Biot's moduli will be approximated from other input variables),EBIOTM(I)=3*(1-EBIOTA(I))*(EBIOTA(I)-PORSTD(I))*(1-2*EPOISS(I))/EMODUL(I)

3.6.53 MROCKD

MROCKD – Flag indicating whether rock densities are constant.

Possible Values:

0: Rock densities are constant for all grid elements.

1: Rock densities are variable for grid elements.

3.6.54 EROCKD <<or>>

EROCKD(I), for I = 1, NB

EROCKD or EROCKD(I) – Rock densities for each grid element. Unit: gram/cm^3

Note: If MROCKD = 0 (rock densities are constant for all grid elements), only one value is required by the program.

If MROCKD = 1 (rock densities are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.55 MINITSTR

MINITSTR – Flag indicating whether initial (in-situ) stresses are specified at reference depth with defined stress gradient or input as grid element data.

Possible Values:

0: Initial (in-situ) stresses are specified at reference depth with defined stress gradient, user needs to further input STRXX_REF, STRYY_REF, STRZZ_REF, STR_DEPTH, STRXX_GRAD, STRYY_GRAD, STRZZ_GRAD as follows.

1: Initial (in-situ) stresses are input as grid element data, user needs to further input MINITSTRXX, ESTRXX_INIT, MINITSTRYY, ESTRYY_INIT, MINITSTRZZ, ESTRZZ_INIT as follows.

3.6.56 STRXX_REF, STRYY_REF, STRZZ_REF, STR_DEPTH

NOTE: Input only if MINITSTR = 0

STRXX_REF – σ_{xx} at reference depth, positive in extensive stress. Units: psi

STRYY_REF – σ_{yy} at reference depth, positive in extensive stress. Units: psi

STRZZ_REF – σ_{zz} at reference depth, positive in extensive stress. Units: psi

STR_DEPTH – Reference depth. Units: ft.

3.6.57 STRXX_GRAD, STRYY_GRAD, STRZZ_GRAD

NOTE: Input only if MINITSTR = 0

STRXX_GRAD – Z directional gradient for σ_{xx}. Units: psi/ft.

STRYY_GRAD – Z directional gradient for σ_{yy}. Units: psi/ft.

STRZZ_GRAD – Z directional gradient for σ_{zz}. Units: psi/ft.

3.6.58 MINITSTRXX

NOTE: Input only if MINITSTR = 1

MINITSTRXX – Flag indicating whether initial (in-situ) σ_{xx} are constant.

Possible Values:

0: Initial (in-situ) σ_{xx} are constant for all grid elements.

1: Initial (in-situ) σ_{xx} are variable for grid elements.

3.6.59 ESTRXX_INIT <<or>>

ESTRXX_INIT(I), for I = 1, NB

NOTE: Input only if MINITSTR = 1

ESTRXX_INIT or ESTRXX_INIT(I) – σ_{xx} for each grid element. Unit: psi

Note: If MINITSTRXX = 0 (σ_{xx} are constant for all grid elements), only one value is required by the program.
If MINITSTRXX = 1 (σ_{xx} are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.60 MINITSTRYY

NOTE: Input only if MINITSTR = 1

MINITSTRYY – Flag indicating whether initial (in-situ) σ_{yy} are constant.

Possible Values:

0: Initial (in-situ) σ_{yy} are constant for all grid elements.

1: Initial (in-situ) σ_{yy} are variable for grid elements.

3.6.61 ESTRYY_INIT <<or>>

ESTRYY_INIT(I), for I = 1, NB

NOTE: Input only if MINITSTR = 1

ESTRYY_INIT or ESTRYY_INIT(I) – σ_{yy} for each grid element. Unit: psi

Note: If MINITSTRYY = 0 (σ_{yy} are constant for all grid elements), only one value is required by the program.
If MINITSTRYY = 1 (σ_{yy} are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.6.62 MINITSTRZZ

NOTE: Input only if MINITSTR = 1

MINITSTRZZ – Flag indicating whether initial (in-situ) σ_{zz} are constant.

Possible Values:

0: Initial (in-situ) σ_{zz} are constant for all grid elements.

1: Initial (in-situ) σ_{zz} are variable for grid elements.

3.6.63 ESTRZZ_INIT <<or>>

ESTRZZ_INIT(I), for I = 1, NB

NOTE: Input only if MINITSTR = 1

ESTRZZ_INIT or ESTRZZ_INIT(I) – σ_{zz} for each grid element. Unit: psi

Note: If MINITSTRZZ = 0 (σ_{zz} are constant for all grid elements), only one value is required by the program.
If MINITSTRZZ = 1 (σ_{zz} are variable for grid elements), NB values are required by the program. The data input ordering follows the convention that Y direction is the fastest changing direction, then Z direction is the second fastest changing direction, and X direction is the slowest changing direction when IXYZ = 0. When IXYZ = 1, X direction

is the fastest changing direction, then Y direction is the second fastest changing direction, and Z direction is the slowest changing direction.

3.7 Recurrent Well Condition Data

The last input section consists of the well condition data. Well conditions can be changed by repeating the input data in this input section. The well conditions specified on line 3.7.3 will be simulated from the previous TM until the newly specified TM on line 3.7.1. Since a negative value will terminate the simulation, input line 3.7.1 should be the very last line of an input data file and it should have a negative value for TM. Three comment lines precede each data line.

3.7.0 Comment Lines
There are 7 comment lines, to be used for describing the reservoir grid options. Each comment line can be up to 70 characters long.

3.7.1 TM, DT, NWELLS, GORLIM, WORLIM

TM – Maximum time
Units: days (if IPV=0) or pore volume injected (if IPV=1)
Note: This value is ignored when INUG=1 unless IESOCF=0.

DT – Time-step size.
Units: days
Note: This value is used only if MDT=0.

NWELLS - Number of wells for which the injection/production conditions will be specified.

GORLIM - GOR limit on run termination.
Units: MSCF/STB
Note: Set to -1.0 to deactivate this option.

WORLIM - WOR limit on run termination.
Units: STB/STB
Note: Set to -1.0 to deactivate this option.

3.7.2 IESOCF, IHCLIM, HCLIM, H2OLIMO (This line is read only if INUG=1)

IESOCF - Flag used to indicate how a change in boundary conditions or the end of a simulation is determined.
Possible Values:
0 : Change in boundary conditions or end of simulation is based on time (in days)—the limit is then specified by input parameter TM
1 : Change in boundary conditions or end of simulation is based on maximum lb-moles of component IHCLIM injected—the limit is then specified by input parameter HCLIM
2 : Change in boundary conditions or end of simulation is based on maximum STB brine injectedthe limit is then specified by input parameter H2OLIM
Note: Values of 1 and 2 for IESOCF allow multiple WAG cycles, for example, to be modeled during a single simulation when using pressure-specified injection boundary conditions.

IHCLIM - Index that identifies component to be used for specifying boundary condition

change or end of simulation when IESOCF=1.

Note: IHCLIM is ignored unless IESOCF=1.

HCLIM - Maximum amount of component IHCLIM to be injected before changing boundary conditions or ending a simulation.

Units: lb-mole

Note: HCLIM is ignored unless IESOCF=1.

H2OLIM - Maximum amount of brine to be injected before changing boundary conditions or ending a simulation.

Units: STB

Note: H20LIM is ignored unless IESOCF=2.

3.7.3 DTMAX, DTMIN, DSLIM, DPLIM, DVLIM, DMFACT

DTMAX - Maximum time step allowed.

Units: days

DTMIN - Minimum time step allowed.

Units: days

DSLIM - Maximum change in phase saturation tolerated at each grid block.

Units: fraction

DPLIM - Maximum relative change in pressure tolerated at each grid block.

Units: fraction

DVLIM - Maximum relative volume error tolerated at each grid block.

Units: fraction

DMFACT - Maximum relative change of component moles tolerated at each grid block.

Units: fraction

Note: These values are used only if MDT=1. The proper values for DTMAX, DTMIN, DSLIM, DPLIM, DVLIM, and DMFACT depend on reservoir size, phase behavior, etc. As a rule of thumb, DTMIN=$0.01\Delta t_{start}$ and DTMAX=$0.25\Delta t_{start}$ where the time step size, Δt_{start}, is computed so that the Courant number for the smallest gridblock is 0.05. Proper values for DPLIM can be from 0.01 to 0.001. Reasonable values for DSLIM, DVLIM, and DMFACT are in the order of 0.05.

Lines 3.7.4 through 3.7.13 are repeated for LW=1, NWELLS

Note: Depending on the well conditions (called well type), a different set of input lines is required for each well. A total of NWELLS sets of input lines are required and each set contains two or three input lines. Each set of input lines starts with input line 3.7.4, which specifies the LW^{th} well type and is followed by one to four additional lines. Therefore, input lines 3.7.4 through 3.7.13 are repeated for LW=1, NWELLS as specified below:

(1) If the well is a constant total molar or volumetric injection well, IQTYPE=1, then use input lines 3.7.5, 3.7.8-3.7.10.

(2) If the well is a constant bottom-hole pressure injection well, IQTYPE=2, then use input lines 3.7.6, 3.7.8-3.7.10.

(3) If the well is a constant surface rate injection well, IQTYPE=4, then use input lines 3.7.7-3.7.10.

(4) If the well is a constant total molar or volumetric production well, IQTYPE= -1, then use input line 3.7.11

(5) If the well is a constant bottom-hole pressure production well, IQTYPE=-2, then use input line 3.7.12.

(6) If the well is a constant surface oil rate production well, IQTYPE=-4, then use

input line 3.7.13.

3.7.4 LW, IQTYPE

LW - Well number.

IQTYPE(LW) - Flag indicating type of LW^{th} well.

Possible Values:

1 : Well is a constant total molar injection well
2 : Well is a constant bottom-hole pressure injection well
4 : Well is a constant surface rate injection well
-1 :Well is a constant total molar production well
-2 : Well is a constant bottom-hole pressure production well
-4 : Well is a constant surface oil production well

3.7.5 QTMLC(I), FWMLC(I), NCOMP(I), ISWITCH(I), PBHC(I) (This line is read only if IQTYPE(I)=1)

QTMLC(I) - Total (water plus hydrocarbon) molar injection flow rate (positive) for I^{th} well.

Units: lbmoles/day

FWMLC(I) - Water molar fraction for I^{th} well.

Units: fraction

NCOMP(I) - Number of components composing the hydrocarbon portion of the injected stream for I^{th} well.

Possible Values: 0 through NC, inclusive

ISWITCH(I) - Flag indicating whether I^{th} well switches from constant total molar rate.

Possible Values:

0 : Switching does not occur
1 : Switching occurs at PBHC(I) specified

PBHC(I) - The bottom-hole pressure for switching if ISWITCH(I)=1 on this input line.

Units: psi

3.7.6 PBHC(I), FWMLC(I), NCOMP(I), ISWITCH(I), RATESC(I), and/or ANG(I) (This line is read only if IQTYPE(I)=2)

PHBC(I) - Constant bottom-hole injection pressure for I^{th} well.

Units: psi

FWMLC(I) - Water molar fraction for I^{th} well.

Units: fraction

NCOMP(I) - Number of components composing the hydrocarbon portion of the injected stream for I^{th} well.

Possible Values: 0 through NC, inclusive

ISWITCH(I) - Flag indicating whether I^{th} well switches from Pressure.

Possible Values:

0 : Switching does not occur
1 : Switching occurs at RATESC(I) specified

RATESC(I) - The rate for switching if ISWITCH(I)=1 on this input line (for gas injection).

Units: Mscf/day

ANG(I) - Angle for radial flow into grid blocks adjacent to the I^{th} well.
Units: radians
Note: This value is read only if the variable-width cross-section option is active (INUG=1).

Note: The constant bottom-hole pressure option cannot be used if IFLAGT>0 *and* IQTYPE(I)>0 *and* NCOMPT(I)>0. Only constant rate option can be used.

3.7.7 QPSVC(I,1), QPSVC(I,3), NCOMP(I), ISWITCH(I), PBHC(I), and RATESC(I) (This line is read only if IQTYPE(I)=4)

QPSVC(I,1) – Surface condition water injection for I^{th} well.
Units: stb/day

QPSVC(I,3) – Surface condition gas injection for I^{th} well.
Units: MSCF/day

NCOMP (I) - Number of components composing the hydrocarbon portion of the injected stream for I^{th} well.
Possible Values: 0 through NC, inclusive

ISWITCH(I) - Flag indicating whether I^{th} well switches from constant total molar rate to constant bottom-hole pressure injection well.
Possible Values:
0 : Switching does not occur
1 : Switching occurs at PBHC(I) specified

PBHC(I) - The bottom-hole pressure for switching if ISWITCH(I)=1 on this input line.
Units: psi

RATESC(I) - The rate for switching if ISWITCH(I)=1 on this input line (for gas injection).
Units: Mscf/day

3.7.8 KC(I,J), Z1(I,J), for J=1, NCOMP (This line is read only if IQTYPE(I)>0 and NCOMP>0)

KC(I,J) - Component number of J^{th} component in I^{th} well.
Note: This number should correspond to the component order specified on input line 3.1.3.

Z1(I,J) - Overall hydrocarbon composition of J^{th} component in I^{th} well.
Units: fraction

3.7.9 NCOMPT(I) (This line is read only if IFLAGT>0 (tracer injection) and IQTYPE(I)>0)

NCOMPT(I) - Number of tracers injected for I^{th} well.

3.7.10 KCTR(I,K), Z1TR(LW(I),K), for K=1, NCOMPT(I) (This line is read only if IFLAGT>0 and IQTYPE(I)>0 and NCOMPT(I)>0)

KCTR(I,K) - Tracer number of K^{th} tracer in I^{th} well.

Z1TR(IW(I),K) - Injection concentration of K^{th} tracer in $LW(I)^{th}$ well.
Units: ppm (if IUNIT(K)=1)
dpm/liter (if IUNIT(K)=2)
meq/ml (if IUNIT(K)=3)

3.7.11 QTMLC(I), ISWITCH(I), PBHC(I) (This line is read only if IQTYPE(I)= -1)

QTMLC(I) - Total (water plus hydrocarbon) molar production rate (negative) for I^{th} well. Units: moles/day

ISWITCH(I) - Flag indicating whether I^{th} well switches from constant total rate to constant bottom-hole pressure production well.

Possible Values:

0 : Switching does not occur

1 : Switching occurs at PBHC(I) specified

PBHC(I) - The bottom-hole pressure for switching if ISWITCH(I)=1 on this input line.

Units: psi

3.7.12 PBHC(I) << or >> PBHC(I), ANG(I) (This line is read only if IQTYPE(I)=-2)

PBHC(I) - Constant bottom-hole pressure for I^{th} well.

Units: psi

ANG(I) - Angle for radial flow into grid blocks adjacent to the I^{th} well.

Units: radians

Note: This value is read only if the variable-width cross-section option is active (INUG=1).

3.7.13 QPSVC(I,2), ISWITCH(I), PBHC(I) (This line is read only if IQTYPE(I) = -4)

QPSVC(I,2) – Surface condition oil production for I^{th} well.

Units: stb/day

ISWITCH(I) - Flag indicating whether I^{th} well switches from constant total molar rate to constant bottom-hole pressure injection well.

Possible Values:

0 : Switching does not occur

1 : Switching occurs at PBHC(I) specified

PBHC(I) - The bottom-hole pressure for switching if ISWITCH(I)=1 on this input line.

Units: psi

APPENDIX A: RESTART FEATURES

There is an option that allows users to make restart runs. In order to make a restart run, the results of a previous run need to be used as the initial conditions for the restart run. The required input data files for such a run are described in this section.

A.1 Restart Run Procedure

To make a restart run, two input data files are required. The first data file, which needs modification, is the input data file from a previous run.

Two changes might need to be made to the input data file from the previous run.

(1) Copy TEST.STO to TEST.RES

(2) Set ISTART=2. This will let the program know that the results of a previous run will be used and are now stored in the restart data file, and

(3) The maximum run time (TM), time step size (DT), and well conditions might need to be changed.

It should be realized that a restart run is possible only if the results of a previous run have been stored (ISTORE=1 for that previous run) and the required information for the restart run is in the STORE (TEST.STO) file created. Since the user can specify to write restart information to the STORE file at various time steps, it is necessary for the user to copy the data from the particular time-step that he is interested in to the restart data file. The set of data to be copied from the STORE file to the restart data file should start from the data line containing time in days and pore volumes when it was stored through the data line containing cumulative surface production for that time-step. The STORE file has been formatted such that the format of each printout is the same as that of the restart file. The restart file consists of comment lines and data lines. Each input data line in the restart file is preceded by one comment line that is ignored by the simulator.

A.2 Data Written to Restart Stored Data File (.STO)

The information in the following list is written to the TEST.STO data file.

Printed at each NSTSKIP interval:

- Time in days and pore volumes
- Grid block pressures
- Water saturations
- Phase saturations
- Phase molar densities
- Phase mass densities
- Number of moles in each phase
- Number of moles in each grid block
- Number of components
- Overall compositions
- Component moles in each grid block
- Water phase component moles in each grid block if IFOSW = 1
- Equivalent water mole fraction in water if IFOSW = 1
- Original Water in place
- Original hydrocarbons in place
- Water in place
- Hydrocarbon in place
- Net water production
- Cumulative water injection
- Cumulative water production
- Net hydrocarbon production
- Cumulative hydrocarbon injection
- Cumulative hydrocarbon production
- Original oil and gas in place
- Initial pore volume
- Phase compositions
- Number of phases in each grid block
- Flash index for each grid block
- Molar fraction for each phase (L-V values) Cumulative surface production of water, oil and gas
- Phase compressibility factors
- Tracking component compositions in each phase

For Tracer option (IFLAGT = 1):

- Original Tracer in place
- Tracer in place
- Net tracer production
- Cumulative tracer injection
- Cumulative tracer production
- Tracer concentrations
- Total tracers
- Tracer adsorptions
- Salinity dependent coefficient for tracer adsorptions
- Permeability reduction factor for polymer solution

For Foam option (if IFOAM = 1):
Flag for foam existence (ICHECK) If ICHECK = 1
Foam tracking flag for each block
Relative mobility of gas-foam phase
Viscosity of gas-foam phase
For Foam option (if IFOAM = 2):
Flag for foam existence (ICHECK) If ICHECK = 1
Foam tracking flag for each block
For Foam option (if IFOAM = 3):
Foam tracking flag for each block
Foam texture (bubble density)
Viscosity of gas-foam phase

APPENDIX B: OUTPUT FILES

Appendix B lists the contents of the output files generated by DOECO2.

B.1 Data Written to Well History Data File (.HIS)

DOECO2 version, Header, number of components, number of wells
Name of components
Number of Prints
Following information is written at the specified frequency (NHSSKIP)
- Number, Time (days), DT (days), Time (PV), DT (PV)
- Cumulative hydrocarbon component injection
- Cumulative hydrocarbon component production
- Hydrocarbon component recovery
- Water component cumulative injection and production
- Total surface production rates
- Cumulative surface production
- Oil recovery, GOR, WOR, Average reservoir pressure
- Effluent concentrations
- Hydrocarbon component injection rates
- For Tracer option (If IFLAGT = 1)
  - Cumulative tracer injection
  - Cumulative tracer production
  - Effluent concentration for each well
- Well flowing pressures

B.2 Data Written to Overall History Data File (.TAB)

DOECO2 version, Header, NX, NY, NZ, NB, NP
Written at each specified TPR and at the end of simulation:
- Time, time step size
- Pressures
- Aqueous phase saturations
- Oil phase saturations
- Gas phase saturations
- Second hydrocarbon phase saturations
- Overall compositions of each component
- Phase compositions of components in every phase
- Relative permeabilities
- Viscosities
- Molar densities
- Mass densities
- Written for each well:
  - Well number, location and well flowing pressures
  - GOR, WOR
  - Flowing rates for aqueous, oil and gas phase
  - Component flow rates

Molar Balances for each component and water
Maximum volume error
Total CPU time, computing time, total iterations, average time step size, average CPU time per time-step per grid block
Time used by simulation, user time, system time

B.3 Data Written to Profile Data File (.PRF)

Data written to this file is used for creating 1-D profile plots.
DOECO2 version, Header, NX, NY, NZ, NB, NP, NC, NW
Grid block pressures and phase saturations
Overall compositions
Phase compositions
If (IFLAGT = 1) Tracer name and concentrations
Pressure and capillary pressure
Interfacial tensions
Relative permeabilites and viscosities
Phase mass and molar densities
If number of phases present is more than 2
Residual phase saturations
Relative permeability end points
Relative permeability exponents
Capillary numbers
Trapping numbers
Effective dispersivities

B.4 Data Written to Contour Data File (.CON)

Data written to this file is used for creating contour plots.
DOECO2 version, Header, NX, NY, NZ, NB, NP, NC, NW TCT, MCTP, MCTSAT, MCTOMFR, MCTPMFR, MCTPRO DELTA X, DELTA Y, DELTA Z
Well number and location
Time in days and pore volumes
Pressures
Phase Saturations
Overall component compositions
Phase mole fractions
Relative permeabilites
Viscosities
Phase molar densities
Phase mass densities

APPENDIX C: HINTS USING ITERATIVE SOLVER

One may obtain thirty-six different iterative solvers by using different preconditioners and solution methods. There are three iterative solvers, four preconditioners (one is null) and three solution methods. However, only a few of these combinations are effective enough to be used in reservoir simulation problems. Considering the diversity of these problems, it is almost impossible to select one single iterative solver for all purposes. However, one can choose several iterative solvers based on user experience. The following are recommended for general use: (1) J-BCGS, (2) MIC-BCGS, and (3) MIC-OMIN. It is recommended that the user first try J-BCGS, then MIC-BCGS, and finally MIC-OMIN. J-BCGS usually works effectively in both 2-D and 3-D problems. However, depending on the problem, this solver may face non- convergence problems. Also, it requires more iterations than the others. The second choice, MIC-BCGS, is usually somewhat slower than J-BCGS, but it generally seems to converge with fewer iterations whenever J-BCGS has difficulty converging. The third solver, MIC-OMIN, is usually effective with 2-D problems. If the pressure matrix is extremely unconditioned, it may not obtain a solution. However, it is reliable and usually faster than MIC-BCGS in 2-D problems. If any of the above mentioned iterative solvers do not work, the user is encouraged to increase the tolerance, usually one order of magnitude larger than those used in the flash calculations (for example, TOLFLA=1.0E-08, ZETA=1.0E-07). The method of solution parameter, METHSL, should usually be set to 1 (FORTRAN) or 2 (FOLRP). Generally, a value of 1 is preferred and a value of 3 (wave method) should not be used due to the inefficiency of the wave method. The modification factor, OMEGA, should be set to 1.0 whenever the MIC preconditioner is used.

APPENDIX D: VISUALIZATION-OUTPUT POST PROCESSING

The S3GRAF software from Sciencesoft was selected for post processing simulation results. It utilizes four output files i.e. TEST.S3ECH, TEST.S3HIS, TEST.S3PERM, and TEST.S3TAB. User can drag one of the files or open one of them in S3GRAF to see the solution and summary of the runs. Once the data is processed, S3GRAF allows the user to select/plot history file data (summary) and see the selected parameters versus time or pore volume; and also select the gridblock properties to see the profile for the selected property in each time such as relative permeabilities, saturations, or reservoir pressure.

APPENDIX E: 2D MESH FILE FOR UNSTRUCTURED GRID

This section shows how to construct a mesh file for 2D unstructured grids.

#Comment line

#Comment line

#NOE (comet line)

Number of Elements value (NOE)

#NOV (comment line)

Number of Vertices value (NOV)

#Thickness (comment line)

Reservoir Thickness value

#Comment

#Comment

#Comment

#Vertices X values (Comment line)

Vertices X coordinate values in a row (XCRD)

#Comment

#Vertices Y values (Comment line)

Vertices Y coordinate values in a row (YCRD)

#Comment

#Comment

#Number of vertices for each element (comment line)

Number of Vertices values for every element in a row (NOFV)

#Comment

#Comment

#Comment

#Comment

#Connectivity for each element (comment line)

Element connectivity values (ELCON)

#END

A mesh file example is shown below.

```
GeneralDataFile
ProblemSize
NOE
4
NOV
9
DEPTH
100
!CC
MeshDatabase
NodesCoordinates
XGP
       0.00000
     280.00000
       0.00000
     280.00000
     560.00000
       0.00000
     280.00000
     560.00000
     560.00000
!CC
YGP
       0.00000
       0.00000
     280.00000
     280.00000
       0.00000
     560.00000
     560.00000
     280.00000
     560.00000
!CC
NumberOfVerticesOfEachElement
NOFV
         4
         4
         4
         4

Conectivities:
Node(1)   Node(2)   Node(3)     Node(4)
ElementConectivity
ELCON
         3         4         7         6
         1         2         4         3
```

4	8	9	7
2	5	8	4

APPENDIX F: 3D MESH FILE FOR UNSTRUCTURED GRID

This section shows how to construct a mesh file for 3D unstructured grids. Now, no comment lines are written:

DUMMY VALUE

NOV NOT NOPr NOH NOPy DummyValue DummyValue

XCRD(I) YCRD(I) ZCRD(I) : for I=1 to NOV

CONECTIVITY(I, J) : for I=1 to NOE; for J=1, NOFV(I)

Where,

NOV – Number of Vertices

NOE – Number of Elements (NOT+NOPr+NOH+NOPy)

NOT – Number of Tetrahedron Elements

NOPr – Number of Prisms Elements

NOH – Number of Hexahedron Elements

NOPy – Number of Pyramids Elements

A mesh file example is shown below.

1128683573

8 0 0 1 0 1 1

0 0 0

560 0 0

0 560 0

560 560 0

0 0 100

560 0 100

0 560 100

560 560 100

1 2 3 4 5 6 7 8

APPENDIX G: MESH FILE FOR CORNER POINT GRID

This section shows how to construct a mesh file for boundary-fitted scheme.

G.1 IGRIDTYPE=0

This grid type is based on the CMG Builder file and is shown bellow,

#Comment line

IGridTypeFlag (Must be 0 for this kind of file)

#Comment line

NX NY NZ

#Comment line

X-Coordinate and Y-Coordinate pair values

#Comment line

#Comment line

Zcoordinate values

The example file shown bellow provides COORD data for a i = 4, j = 2, k = 1 corner grid. Note that the X and Y direction grid spacings are uniformly 100 units, respectively.

```
IGRIDTYPE
    0
GRID CORNER
    4    2    1
COORD
    0   0 0   0     0 1      100   0 0 100   0 1
    200   0 0 200   0 1      300   0 0 300   0 1
    400   0 0 400   0 1

      0 200 0   0 200 1      100 200 0 100 200 1
    200 200 0 200 200 1      300 200 0 300 200 1
    400 200 0 400 200 1

      0 400 0   0 400 1      100 400 0 100 400 1
    200 400 0 200 400 1      300 400 0 300 400 1
    400 400 0 400 400 1
```

ZCORN

```
2000 2001 2001 2002 2002 2003 2003 2004
2000 2001 2001 2002 2002 2003 2003 2004
2000 2001 2001 2002 2002 2003 2003 2004
2000 2001 2001 2002 2002 2003 2003 2004
2010 2011 2011 2012 2012 2013 2013 2014
2010 2011 2011 2012 2012 2013 2013 2014
2010 2011 2011 2012 2012 2013 2013 2014
2010 2011 2011 2012 2012 2013 2013 2014
```

G.2 IGRIDTYPE=1

The XAC and YAC data for a i = 4, j = 2, k = 1 corner grid is shown below. that the X and Y direction grid spacings are uniformly 100 units, respectively.

IGRIGTYPE
1
NX NY NZ
4 2 1

XAC()=
0 100 200 300 400
0 100 200 300 400
0 100 200 300 400

0 100 200 300 400
0 100 200 300 400
0 100 200 300 400

YAC()=
0 0 0 0 0
200 200 200 200 200
400 400 400 400 400

0 0 0 0 0
200 200 200 200 200
400 400 400 400 400