

## Final Report for the Period September 30, 1992 to December 31, 1995

**By**  
**Enhanced Oil and Gas Recovery Research Program**  
**The University of Texas at Austin**

**July 1996**

Performed Under Contract No. DE-AC22-92BC14885

**The University of Texas at Austin  
Austin, Texas**

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Bartlesville, Oklahoma**

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DOE/BC/14885-15  
Distribution Category UC-122

User's Guide for UTCHEM Implicit (1.0)  
A Three Dimensional Chemical Flood Simulator

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## 1.0 INTRODUCTION

UTCHEM IMPLICIT is a three-dimensional chemical flooding simulator. The solution scheme is fully implicit. The pressure equation and the mass conservation equations are solved simultaneously for the aqueous phase pressure and the total concentrations of each component. A third-order-in-space, second-order-in-time finite-difference method and a new total-variation-diminishing (TVD) third-order flux limiter are used to reduce numerical dispersion effects. Saturations and phase concentrations are solved in a flash routine. The major physical phenomena modeled in the simulator are:

- dispersion
- adsorption
- aqueous-oleic-microemulsion phase behavior
- interfacial tension
- relative permeability
- capillary trapping
- compositional phase viscosity
- capillary pressure
- phase density
- polymer properties:
  - shear thinning viscosity
  - inaccessible pore volume
  - permeability reduction
  - adsorption

The following options are available in the simulator: constant or variable time-step sizes, uniform or nonuniform grid, pressure or rate constrained wells, horizontal and vertical wells.

Notes:

## 2.0 OPERATION OF THE SIMULATOR

### 2.1 Input and Output Files

UTCHEM IMPLICIT requires one input file. A detailed input data description is given in section 3. A sample input file is given in section 5. The number of history plot files depends on number of wells (NW). The FORTRAN unit number for the history plot file is incremented by one for each well. For example, if NW is equal to three, then three history plot files would be generated corresponding to FORTRAN unit numbers 5, 6, and 7. The input and output files are summarized in the following table.

<u>Unit Number</u>	<u>File Name</u>	<u>Contents</u>
1	INPT	Input data; described in detail in section 3.0
2	ECHO	Echo print of the input file information
3	PROF	Formatted profile data described in Appendix 6.1
4	SUMA	Summary data described in Appendix 6.2
5+i	HSTi	Well history plotting data for i-th well described in Appendix 6.3

### 2.2 Source Code Array Dimensions

The parameters in the following table are used by the simulator to define array sizes.

<u>Parameter</u>	<u>Definition</u>
NXM	Number of grid blocks in X-direction
NYM	Number of grid blocks in Y-direction
NZM	Number of grid blocks in Z-direction
NC	Number of components (currently set to be six)
NW	Number of wells
NWB	Maximum number of well blocks



Notes:

### 3.0 INPUT DATA DESCRIPTION

The UTCHEM IMPLICIT input file consists of comment lines and data lines. All comment lines are ignored by the the simulator. It is important to note, however, that the number of comment lines between data lines is fixed. The first twenty-two 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. The input file is basically divided into five sections and each of those input sections is preceded by an additional seven comment lines. The user should update the comment lines as the input file is modified in order to make using the simulator easier.

All data is free-formatted. This means that for each read statement, it is only necessary to leave a blank space between data elements. Note that the first data element for a given read statement must be on a new line in the input file. Subsequent data elements for that read statement can span as many lines as necessary. Implicit type matching is used; that is, all REAL variables begin with the letters A-H or O-Z and all integer variables begin with the letters I-N.

The following is a list of variables as they are read by UTCHEM. 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. All of the variables listed in the input description will be read by the program unless otherwise noted; therefore, a dummy value will be read by the program for variables not pertinent to the problem being run.

Notes:

### 3.1 Title and Reservoir Description Data

The first input section consists of the title and reservoir description data. Please remember that there are 22 comment lines at the beginning of this section and that each data line is preceded by three comment lines.

#### 3.1.1 RUNNO

**RUNNO** - Run number.

Note: The run number can consist of any combination of alphanumeric characters on a single line (not to exceed 80 characters). This information will be printed as the first line of every output file.

#### 3.1.2 TITLE

**TITLE** - Title and run description.

Note: The title can consist of any combination of alphanumeric characters spanning three lines in the input file (not to exceed 80 characters per line). Please note that the title must span three lines and that any of those lines can be blank.

#### 3.1.3 T0, TMAX, IPV

**T0** - Time when simulation starts.

**TMAX** - Time when simulation finish.

**IPV** - Flag indicating units for T0 and TMAX.

Possible Values:

- 0 - Days
- 1 - Pore Volumes

#### 3.1.4 IDISPC, ITVD

**IDISPC** - Flag for choosing finite-difference descrization schemes.

Possible Values:

- 1 - Single point upstream method
- 2 - Two point upstream method
- 3 - High-order method

**ITVD** - Flag for using TVD flux-limiter.

Possible Values:

- 0 - Without TVD flux-limiter
- 1 - With TVD flux-limiter

Note: TVD flux-limiter is recommended to use when IDISPC=2 or 3.

#### 3.1.5 TOLE, ITMAX

**TOLE** - Tolarence of primary variable iteration errors

### 3.1.6 DX(I), for I = 1, NX

DX(I) - Grid size of I<sup>th</sup> block in X direction.  
Units: feet

### 3.1.7 DY(J), for J = 1, NY

DY(J) - Grid size of J<sup>th</sup> block in Y direction.  
Units: feet

### 3.1.8 DZ(K), for K = 1, NZ

DZ(K) - Grid size of K<sup>th</sup> block in Z direction.  
Units: feet

### 3.1.9 ICF(KC), for KC = 1, N

ICF(KC) - Flag indicating if KC<sup>th</sup> component is included in the concentration calculations or not.

Possible Values:

- 0 - The KC<sup>th</sup> component is not included in the calculations
- 1 - The KC<sup>th</sup> component is included in the calculations

### 3.2 Reservoir Properties

The second input section consists of the reservoir properties. Please remember that there are seven comment lines at the beginning of this section and that each data line is preceded by three comment lines.

#### 3.2.1 POR(I), for $I = 1, NX \times NY \times NZ$

POR(I) - Porosity of  $I^{\text{th}}$  grid block

Units: fraction

Note: The three-dimensional grid system is being read into a one-dimensional array. The first index (column) of the three-dimensional system varies fastest, the second index (row) varies next fastest, and the third index (layer) varies slowest.

Example: If you had a  $4 \times 3 \times 2$  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

#### 3.2.2 PERMX(I), for $I = 1, NX \times NY \times NZ$

PERMX(I) - Permeability of the  $I^{\text{th}}$  grid block in the X direction

Units: millidarcies

Note: See the note and example for input line 3.2.1 for the order of the permeability values.

#### 3.2.3 PERMY(I), for $I = 1, NX \times NY \times NZ$

PERMY(I) - Permeability of the  $I^{\text{th}}$  grid block.

Units: millidarcies =  $10^{-3} \mu\text{m}^2$

Note: See the note and example for input line 3.2.1 for the order of the permeability values.

#### 3.2.4 PERMZ(I), for $I = 1, NX \times NY \times NZ$

PERMZ(I) - Permeability of the  $I^{\text{th}}$  grid block.

Units: millidarcies ( $10^{-3} \mu\text{m}^2$ )

Note: See the note and example for input line 3.2.1 for the order of the permeability values.

#### 3.2.5 IDEPTH, THETAX, THETAY

IDEPTH - Flag indicating type of depth measurement of the top layer.

Possible Values:

- 0 - Single value for depth of the top layer is specified
- 1 - Depth of each grid block in the top layer is specified

THETAX - Reservoir dip angle in X direction, positive downward.  
Units: radians

THETAY - Reservoir dip angle in Y direction, positive downward.  
Units: radians

3.2.6 D111 (This line is read only if IDEPTH = 0)

D111 - Depth of the top layer of the reservoir measured from the surface (reference plane), positive downward.  
Units: feet

3.2.7 EL(I), for I = 1, NX × NY (This line is read only if IDEPTH = 1)

EL(I) - Depth of I<sup>th</sup> grid block in the top layer (K=1).  
Units: feet

Note: See the note and example for input line 3.2.1 for the order of the grid block depths.

3.2.8 P(I), for I = 1, NX × NY × NZ

P(I) - Initial pressure of each grid block in the reservoir.  
Units: psia

Note: See the note and example for input line 3.2.1 for the order of the initial pressure values. This is assumed to be the aqueous phase pressure.

3.2.9 C1(I), I = 1, NX × NY × NZ

C1(I) - Initial total concentration of component 1 for I<sup>th</sup> block.  
Units: fraction of pore volume

Note: See the note and example for input line 3.2.1 for the order.

3.2.10 C2(I), I = 1, NX × NY × NZ

C2(I) - Initial total concentration of component 2 for I<sup>th</sup> block.  
Units: fraction of pore volume

Note: See the note and example for input line 3.2.1 for the order.

3.2.11 C3(I), I = 1, NX × NY × NZ

C3(I) - Initial total concentration of component 3 for I<sup>th</sup> block.  
Units: fraction of pore volume

Note: See the note and example for input line 3.2.1 for the order.

3.2.12 C4(I), I = 1, NX × NY × NZ

C4(I) - Initial total concentration of component 4 for I<sup>th</sup> block.  
Units: wt%

Note: See the note and example for input line 3.2.1 for the order.

3.2.13 C50(I), I = 1, NX × NY × NZ

C50 - Initial brine salinity.

Units: meq/ml of brine

Note: This is assumed to be all the anions (in equivalents).

Note: See the note and example for input line 3.2.1 for the order.

3.2.14 C60(I), I = 1, NX × NY × NZ

C60 - Initial divalent cation concentration of brine.

Units: meq/ml of brine

Note: See the note and example for input line 3.2.1 for the order.



Notes:

### 3.3 Physical Property Data

The third input section consists of the physical property data. Please remember that there are seven comment lines at the beginning of this section and that each data line is preceded by three comment lines.

#### 3.3.1 EPSME

EPSME - Critical micelle concentration (CMC)—minimum surfactant concentration for the formation of micelles.

Units: volume fraction.

#### 3.3.2 C3MAX0, C3MAX1, C3MAX2

C3MAX0 - Maximum height of binodal curve associated with surfactant at zero salinity.

Units: volume fraction

C3MAX1 - Maximum height of binodal curve associated with surfactant at optimal salinity.

Units: volume fraction

C3MAX2 - Maximum height of binodal curve associated with surfactant at twice optimal salinity.

Units: volume fraction

#### 3.3.3 CSEL, CSEU

CSEL - Lower effective salinity limit for type III phase region.

Units: meq/ml

CSEU - Upper effective salinity limit for type III phase region

Units: meq/ml

#### 3.3.4 G11, G12, G13, G21, G22, G23

G11, G12, G13 - Interfacial tension parameters for water-microemulsion interface.

G21, G22, G23 - Interfacial tension parameters for oil-microemulsion interface.

Units: Dimensionless

#### 3.3.5 XIFTW

XIFTW -  $\log_{10} \sigma_{wo}$  where  $\sigma_{wo}$  is the interfacial tension of the water-oil interface.

Units: dynes/cm = mN/m

#### 3.3.6 T11, T22, T33

T11 - Capillary desaturation curve parameter for aqueous phase.

T22 - Capillary desaturation curve parameter for oleic phase.

T33 - Capillary desaturation curve parameter for microemulsion phase.

3.3.7 S1RW(I), for  $I = 1, NX \times NY \times NZ$

S1RW(I) - Residual saturation of aqueous phase displaced by oil at low capillary number for  $I^{\text{th}}$  grid block.  
Units: fraction

3.3.8 S2RW(I), for  $I = 1, NX \times NY \times NZ$

S2RW(I) - Residual saturation of oleic phase displaced by water at low capillary number for  $I^{\text{th}}$  grid block.  
Units: fraction

3.3.9 S3RW(I), for  $I = 1, NX \times NY \times NZ$

S3RW(I) - Residual saturation of microemulsion phase displaced by water or oil at low capillary number for  $I^{\text{th}}$  grid block.  
Units: fraction

3.3.10 P1RW(I), for  $I = 1, NX \times NY \times NZ$

P1RW(I) - Endpoint relative permeability of water at low capillary number for  $I^{\text{th}}$  grid block.  
Units: dimensionless

3.3.11 P2RW(I), for  $I = 1, NX \times NY \times NZ$

P2RW(I) - Endpoint relative permeability of oil at low capillary number for  $I^{\text{th}}$  grid block.  
Units: dimensionless

3.3.12 P3RW(I), for  $I = 1, NX \times NY \times NZ$

P3RW(I) - Endpoint relative permeability of microemulsion at low capillary number for  $I^{\text{th}}$  grid block.  
Units: dimensionless

3.3.13 E1W(I), for  $I = 1, NX \times NY \times NZ$

E1W(I) - Relative permeability exponent of aqueous phase at low capillary number for  $I^{\text{th}}$  grid block.  
Units: dimensionless

3.3.14 E2W(I), for  $I = 1, NX \times NY \times NZ$ 

E2WC(K) - Relative permeability exponent of oleic phase at low capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.15 E3W(I), for  $I = 1, NX \times NY \times NZ$ 

E3W(I) - Relative permeability exponent of microemulsion phase at low capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.16 S1RC(I), for  $I = 1, NX \times NY \times NZ$ 

S1RC(I) - Residual saturation of aqueous phase displaced by oil at high capillary number for  $I^{\text{th}}$  grid block.

Units: fraction

3.3.17 S2RC(I), for  $I = 1, NX \times NY \times NZ$ 

S2RC(K) - Residual saturation of oleic phase displaced by water at high capillary number for  $I^{\text{th}}$  grid block.

Units: fraction

3.3.18 S3RC(I), for  $I = 1, NX \times NY \times NZ$ 

S3RC(I) - Residual saturation of microemulsion phase displaced by water or oil at high capillary number for  $I^{\text{th}}$  grid block.

Units: fraction

3.3.19 P1RC(I), for  $I = 1, NX \times NY \times NZ$ 

P1RC(I) - Endpoint relative permeability of water at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.20 P2RC(I), for  $I = 1, NX \times NY \times NZ$ 

P2RC(K) - Endpoint relative permeability of oil at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.21 P3RC(I), for  $I = 1, NX \times NY \times NZ$ 

P3RC(I) - Endpoint relative permeability of microemulsion at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.22 E1C(I), for  $I = 1, NX \times NY \times NZ$ 

E1W(I) - Relative permeability exponent of aqueous phase at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.23 E2C(I), for  $I = 1, NX \times NY \times NZ$ 

E2C(K) - Relative permeability exponent of oleic phase at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

3.3.24 E3C(I), for  $I = 1, NX \times NY \times NZ$ 

E3C(I) - Relative permeability exponent of microemulsion phase at high capillary number for  $I^{\text{th}}$  grid block.

Units: dimensionless

## 3.3.25 VIS1, VIS2

VIS1 - Water viscosity at reference temperature.

Units: cp = mPa.s

VIS2 - Oil viscosity at reference temperature.

Units: cp = mPa.s

## 3.3.26 ALPHA1, ALPHA2, ALPHA3, ALPHA4, ALPHA5

ALPHA1 - Compositional phase viscosity parameter.

ALPHA2 - Compositional phase viscosity parameter.

ALPHA3 - Compositional phase viscosity parameter.

ALPHA4 - Compositional phase viscosity parameter.

ALPHA5 - Compositional phase viscosity parameter.

## 3.3.27 AP1, AP2, AP3

AP1, AP2, AP3 - Parameters used for calculating polymer viscosity at zero shear rate as a function of polymer and electrolyte concentrations.

Units: (wt. %)<sup>-1</sup>, (wt. %)<sup>-2</sup>, (wt. %)<sup>-3</sup>

## 3.3.28 BETAP, CSE1, SSLOPE

BETAP - Parameter for calculating the effective divalent salinity used to calculate polymer viscosity.

Units: dimensionless

CSE1 - Value below which the polymer viscosity is considered to be independent of salinity (minimum value of effective salinity for polymer properties).

Units: meq/ml

SSLOPE - Slope polymer viscosity at zero shear rate vs. effective salinity (ion strength) for polymer properties on a log-log plot—assumed to be constant.

Units: dimensionless

Note: This value is usually large and negative for hydrolyzed polyacrylamides and small and positive for polysaccharides.

### 3.3.29 GAMMAC, GAMHF, POWN

GAMMAC - Coefficient in shear rate equation.

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

GAMHF - Shear rate at which polymer viscosity is one half polymer viscosity at zero shear rate.

Units:  $\text{sec}^{-1}$

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

Units: dimensionless

### 3.3.30 EPHI4, BRK, CRK, RKLIM1, RKLIM2

EPHI4 - Effective porosity for polymer—ratio of apparent porosity for polymer to actual porosity.

Units: dimensionless

BRK - Parameter for calculating permeability reduction factor.

Units:  $\frac{\text{volume of polymer} - \text{rich phase}}{\text{weight\% polymer}}$

CRK - Parameter for calculating permeability reduction factor.

Units:  $(\text{darcy})^{1/2} (100 \text{ g/g})^{-1/3}$

### 3.3.31 DEN1, DEN2, DEN3, IDEN

DEN1 - Specific weight or density of water—Component 1.

Units: psi/ft

DEN2 - Specific weight or density of oil—Component 2.

Units: psi/ft

DEN3 - Specific weight or density of surfactant—Component 3.

Units: psi/ft

IDEN - Flag indicating if gravity effect should be considered.

Possible values:

0 - Do not consider gravity effect

1 - Consider gravity effect

Note: Specific weight for pure water is 0.433 psi/ft (density of 1 g/cm<sup>3</sup>)

3.3.32 CPC(I), for  $I = 1, NX \times NY \times NZ$ 

CPC(I) - Capillary pressure endpoint for  $I^{\text{th}}$  gridblock.

Units:  $\text{psi}\sqrt{\text{darcies}}$

3.3.33 EPC(I), for  $I = 1, NX \times NY \times NZ$ 

EPC(I) - Capillary pressure exponent for  $I^{\text{th}}$  gridblock.

Units: dimensionless

Note: The value for EPC(I) must be non-zero.

## 3.3.34 ALPHAL1, ALPHAT1, ALPHAL2, ALPHAT2, ALPHAL3, ALPHAT3

ALPHAL1 - Longitudinal dispersivity of aqueous phase.

Units: feet

ALPHAT1 - Transverse dispersivity of aqueous phase.

Units: feet

ALPHAL2 - Longitudinal dispersivity of oleic phase.

Units: feet

ALPHAT2 - Transverse dispersivity of oleic phase.

Units: feet

ALPHAL3 - Longitudinal dispersivity of microemulsion phase.

Units: feet

ALPHAT3 - Transverse dispersivity of microemulsion phase.

Units: feet

## 3.3.35 AD31, AD32, B3D, AD41, AD42, B4D

AD31 - Surfactant adsorption parameter.

Units: dimensionless

AD32 - Surfactant adsorption parameter.

Units: ml/meq

B3D - Surfactant adsorption parameter.

Units: dimensionless

AD41 - Polymer adsorption parameter.

Units: dimensionless

AD42 - Polymer adsorption parameter.

Units: ml/meq

B4D - Polymer adsorption parameter.

Units:  $\frac{\text{volume of water}}{\text{weight\% polymer}}$



Notes:

### 3.4 Recurrent Injection/Production Data Set

The fourth input section consists of the recurrent injection/production well data. Please remember that there are seven comment lines at the beginning of this section and that each line is preceded by three comment lines.

#### 3.4.1 TINJ, DLIM, DT, DTMIN, DTMAX, DTMIN

TINJ - Cumulative injection time.

Units: days or pore volumes (dependent on value of IPV flag on input line 3.1.3)

DT - Initial time step size.

Units: days

DLIM - Tolerance of relative changes of primary variables during two consecutive timesteps

Units: dimensionless

DTMIN - Minimum time step size.

Units: days

DTMAX - Maximum time step size.

Units: days

Note: The data on input lines 3.4.2 through 3.4.13 are repeated for  $M = 1$  to NW times.

#### 3.4.2. IW(M), JW(M), KW(M), IDIR(M), ILTH(M), IFLAG(M), RW(M)

IW(M) - First x-index of the gridblocks containing the  $M^{\text{th}}$  well.

Possible Values: Between 1 and NX

JW(M) - First y-index of the gridblocks containing the  $M^{\text{th}}$  well.

Possible Values: Between 1 and NY

KW(M) - First z-index of the gridblocks containing the  $M^{\text{th}}$  well.

Possible Values: Between 1 and NZ

IDIR(M) - Flag indicating the direction in which the  $M^{\text{th}}$  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

ILTH(M) - Total number of gridblocks containing the  $M^{\text{th}}$  well.

Possible Values: Between 1 and the number of gridblocks in well direction

IFLAG(M) - Flag indicating type of well constraint specification for  $M^{\text{th}}$  well.

Possible Values:

1 - Rate constrained injection well

2 - Pressure constrained production well

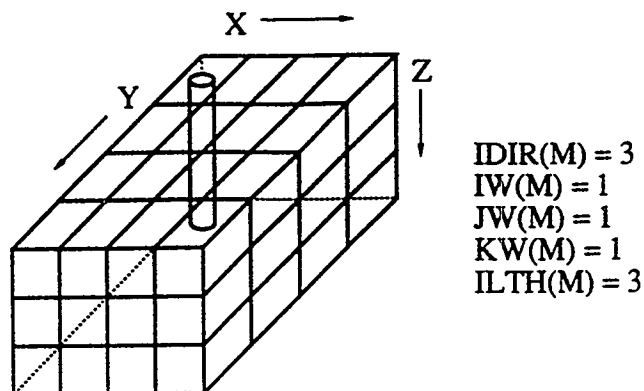
3 - Pressure constrained injection well

## 4 - Rate constrained production well

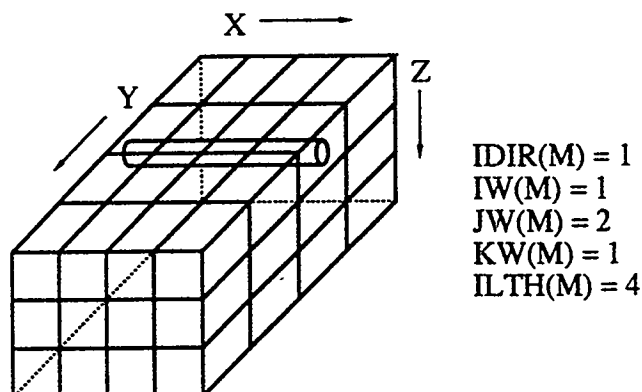
RW(M) - Radius of M<sup>th</sup> well.

Units: feet

Example: For a vertical well (completed through all the layers) as illustrated in the  $4 \times 4 \times 3$  example below, note the values of IDIR(M), IW(M), JW(M), KW(M), and ILTH(M):



For a horizontal well (completed from the first to last gridblock in the X direction and parallel to the X-axis) as illustrated in the  $4 \times 4 \times 3$  example below, note the values of IDIR(M), IW(M), JW(M), KW(M), and ILTH(M):



### 3.4.3 Q1(M), (CQ1 (K), for K=1, NC) (This line is read only if IFLAG(M) = 1)

Q1(M) - Injection rate of aqueous phase in M<sup>th</sup> well

Units: ft<sup>3</sup>/day

CQ1(K) - Concentration of K<sup>th</sup> component in aqueous phase in M<sup>th</sup> well.

Units: vary according to component

Note: The following values for K correspond to the indicated component (corresponding concentration units are in parentheses):

- 1 - Water (volume fraction)
- 2 - Oil (volume fraction)
- 3 - Surfactant (volume fraction)

4 - Polymer (weight percent)

5 - Total nonsorbing anions concentration, assumed to all be chloride anions (meq/ml)

6 - Divalent cations, assumed to all be calcium (meq/ml)

3.4.4 Q2(M) (This line is read only if IFLAG(M) = 1)

Q2(M) - Injection rate of oleic phase in M<sup>th</sup> well

Units: ft<sup>3</sup>/day

3.4.5 Q3(M), (CQ3 (K), for K=1, NC) (This line is read only if IFLAG(M) = 1)

Q3(M) - Injection rate of microemulsion phase in M<sup>th</sup> well

Units: ft<sup>3</sup>/day

CQ3(K) - Concentration of K<sup>th</sup> component in microemulsion phase in M<sup>th</sup> well.

Units: vary according to component (see note for input line 3.4.3)

3.4.6 PWF(M) (This line is read only if IFLAG(M) = 2)

PWF(M) - Flowing bottom hole pressure for the M<sup>th</sup> well.

Units: psia

3.4.7 Q1F(M), (CQ1 (K), for K=1, NC) (This line is read only if IFLAG(M) = 3)

Q1F(M) - Injection cut of aqueous phase in M<sup>th</sup> well

Units: fraction

CQ1(K) - Concentration of K<sup>th</sup> component in aqueous phase in M<sup>th</sup> well.

Units: vary according to component (see note for input line 3.4.3)

3.4.8 Q2F(M) (This line is read only if IFLAG(M) = 3)

Q2F(M) - Injection cut of oleic phase in M<sup>th</sup> well

Units: fraction

3.4.9 Q3(M), (CQ3 (K), for K=1, NC) (This line is read only if IFLAG(M) = 3)

Q3F(M) - Injection cut of microemulsion phase in M<sup>th</sup> well

Units: fraction

CQ3(K) - Concentration of K<sup>th</sup> component in microemulsion phase in M<sup>th</sup> well.

Units: vary according to component (see note for input line 3.4.3)

3.4.10 PWF(M) (This line is read only if IFLAG(M) = 3)

PWF(M) - Flowing bottom hole pressure for the M<sup>th</sup> well.

Units: psia

### 3.4.11 Q(M) (This line is read only if IFLAG(M) = 4)

Q(M) - Total production rate for M<sup>th</sup> well.

Units: ft<sup>3</sup>/day

Note: This value needs to be input as a negative number

### 3.4.12 IP, IC, IS, ICKL, IADS, IVEL, IVIS, IPER, IRKF, IPHSE, ICSE

IP - Flag indicating if pressure data should be printed.

Possible Values:

0 - pressure data will not be printed

1 - pressure data will be printed

IC - Flag indicating if total concentration data should be printed.

Possible Values:

0 - total concentration data will not be printed

1 - total concentration data will be printed

IS - Flag indicating if saturation data should be printed.

Possible Values:

0 - saturation data will not be printed

1 - saturation data will be printed

ICKL - Flag indicating if phase concentration data should be printed.

Possible Values:

0 - Phase concentration data will not be printed

1 - Phase concentration data will be printed

IADS - Flag indicating if adsorption data should be printed.

Possible Values:

0 - Adsorption data will not be printed

1 - Adsorption data will be printed

IVEL - Flag indicating if phase fluxes should be printed.

Possible Values:

0 - Phase fluxes will not be printed

1 - Phase fluxes will be printed

IVIS - Flag indicating if phase viscosities should be printed.

Possible Values:

0 - Phase viscosities will not be printed

1 - Phase viscosities will be printed

IPER - Flag indicating if relative permeabilities should be printed.

Possible Values:

0 - Relative permeabilities will not be printed

1 - Relative permeabilities will be printed

IRKF - Flag indicating if permeability reduction factors should be printed.

Possible Values:

0 - Permeability reduction factors will not be printed

1 - Permeability reduction factors will be printed

IPHSE - Flag indicating if phase environment index should be printed.

Possible Values:

- 0 - Phase environment index will not be printed
- 1 - Phase environment index will be printed

Note: The indices that are printed correspond to the following phase environments:

- 1 - two phase oil/microemulsion
- 0 - single microemulsion phase
- 1 - two phase water/microemulsion
- 2 - two phase oil/water
- 3 - three phase oil/microemulsion/water

ICSE - Flag indicating if effective salinity should be printed.

Possible Values:

- 0 - Effective salinity information will not be printed
- 1 - Effective salinity will be printed

### 3.4.13 WHDT, WPD, INDW

WHDT - Output intervals of production histories

Units: pore volumes or days (dependent on flag INDW)

WPD - Output intervals of profiles

Units: pore volumes or days (dependent on flag INDW)

INDW - Flag for output interval units.

Possible Values:

- 0 - output intervals given in pore volumes injected
- 1 - output intervals given in days

Notes:

#### 4.0 SAMPLE INPUT FILE

The following material is a sample input file for UTCHEM-IMPLICIT (1.0). Each input section is set apart by a header and each data line has three comment lines containing information about the input variables. We strongly recommend that the user take the time to update the comment lines when modifying the input file in order to reduce confusion when running the simulator.

```

CC*****
CC
CC BRIEF DESCRIPTION OF DATA SET : UTCHEM INPLICIT (VERSION 1.0)
CC
CC*****
CC
CC SURFACTANT FLOOD TEST, 5X5X1
CC
CC LENGTH (FT) : 1000          PROCESS : SURFACTANT
CC THICKNESS (FT): 100         INJ. RATE (FT3/DAY) :10000
CC WIDTH (FT) : 1000          COORDINATES : CARTISIAN
CC POROSITY : 0.20
CC GRID BLOCKS : 5X5X1
CC DATE : OCT. 95
CC
CC*****
CC
CC*****
CC
CC RESERVOIR DESCRIPTION
CC
CC*****
CC
CC
*----RUNNO
INPTSF100195
CC
CC
*----HEADER
TESTING UTCHEM IMPLICIT VERSION 1.0
SURFACTANT FLOOD
INPTSF100195
CC
CC INITIAL TIME MAX. SIMULATION TIME UNITS FOR TIME
*---- TO TMAX IPV
      0 6000 0
CC
CC FINITE-DIFFERENCE DESCRIZATION SCHEME OPTION, TVD FLUX-LIMITER OPTION
*----IDISPC ITVD
      3      1
CC
CC ITERATION ERROR TOLERANCE MAXIMUM ITERATION NUMBER ALLOWED
*----TOLE      ITMAX
      1.E-10 50
CC
CC CONSTANT GRID BLOCK SIZE IN X DIRECTION
*----DX1
      5*200
CC

```



```

CC CONSTANT GRID BLOCK SIZE IN Y DIRECTION
*----DY1
      5*200
∞
CC CONSTANT GRID BLOCK SIZE IN Z DIRECTION
*----DZ1
      100
∞
CC FLAG INDICATING IF THE COMPONENT IS INCLUDED IN CALCULATIONS OR NOT
*----ICF(KC) FOR KC=1,NC
      1 1 1 1 1 1
∞
CC*****
CC
CC      RESERVOIR PROPERTIES
CC
CC*****
CC
CC
CC POROSITY
*----PORC1
      25*.2
∞
CC X-PERMEABILITY (MILIDARCY)
*----PERMX
      25*200
∞
CC Y-PERMEABILITY (MILIDARCY)
*----PERMY
      25*200
∞
CC Z-PERMEABILITY (MILIDARCY)
*----PERMZ
      25*200.
∞
CC FLAG FOR CONSTANT OR VARIABLE DEPTH, DIP ANGLES
*----DEPTH THETAX THETAY
      0      0      0
∞
CC CONSTANT DEPTH (FT)
*----D111
      0.
∞
CC INITIAL PRESSURE (PSIA)
*----PRESS1
      25*14.7
∞
CC INITIAL WATER CONCENTRATION
*----C1
      25*.45
∞
CC INITIAL SURFACTANT CONCENTRATION
*----C3
      25*0.
∞
CC INITIAL POLYMER CONCENTRATION
*----C4
      25*0.
∞
CC CHLORIDE CONCENTRATIONS (MEQ/ML)
*----C50
      25*.65
∞
CC CALCIUM CONCENTRATIONS (MEQ/ML)

```

```
*----C60
      25*0.133
CC
CC*****
CC
CC      PHYSICAL PROPERTY DATA
CC
CC*****
CC
CC
CC CMC
*---- EPSME
      .0001
CC
CC HRIGHT OF BINODAL CURVE AT ZERO, OPT., AND 2XOPT SALINITY
*----C3MAX0 C3MAX1 C3MAX2
      0.12 .03 .08
CC
CC LOWER AND UPPER EFFECTIVE SALINITY
*----CSEL CSEU
      .5 .8
CC
CC INTERFACIAL TENSION PARAMETERS
*----G11 G12 G13 G21 G22 G23
      13. -14.8 .007 13. -14.5 .01
CC
CC LOG10 OF OIL/WATER INTERFACIAL TENSION
*----XIFTW
      1.3
CC
CC CAPILLARY DESATURATION PARAMETERS FOR PHASE 1, 2, AND 3
*---- T11 T22 T33
      1865. 59074 364.
CC
CC RES. SATURATION OF PHASE 1 AT LOW CAPILLARY NO.
*----S1RW
      25*0.15
CC
CC RES. SATURATION OF PHASE 2 AT LOW CAPILLARY NO.
*----S2RW
      25*0.4
CC
CC RES. SATURATION OF PHASE 3 AT LOW CAPILLARY NO.
*----S3RW
      25*0.15
CC
CC ENDPOINT REL. PERM. OF PHASE 1 AT LOW CAPILLARY NO.
*----P1RW
      25*.14
CC
CC ENDPOINT REL. PERM. OF PHASE 2 AT LOW CAPILLARY NO.
*----P2RW
      25*.9
CC
CC ENDPOINT REL. PERM. OF PHASE 3 AT LOW CAPILLARY NO.
*----P3RW
      25*.14
CC
CC REL. PERM. EXPONENT OF PHASE 1 AT LOW CAPILLARY NO.
*----E1W
      25*2.
CC
CC REL. PERM. EXPONENT OF PHASE 2 AT LOW CAPILLARY NO.
*----E2W
```

```

25*2.
CC
CC REL. PERM. EXPONENT OF PHASE 3 AT LOW CAPILLARY NO.
*----E3W
25*2.
CC
CC RES. SATURATION OF PHASE 1 AT HIGH CAPILLARY NO.
*----S1RC
25*0.
CC
CC RES. SATURATION OF PHASE 2 AT HIGH CAPILLARY NO.
*----S2RC
25*0.
CC
CC RES. SATURATION OF PHASE 3 AT HIGH CAPILLARY NO.
*----S3RC
25*0.
CC
CC ENDPOINT REL. PERM. OF PHASE 1 AT HIGH CAPILLARY NO.
*----P1RC
25*1.
CC
CC ENDPOINT REL. PERM. OF PHASE 2 AT HIGH CAPILLARY NO.
*----P2RC
25*1.
CC
CC ENDPOINT REL. PERM. OF PHASE 3 AT HIGH CAPILLARY NO.
*----P3RC
25*1.
CC
CC REL. PERM. EXPONENT OF PHASE 1 AT HIGH CAPILLARY NO.
*----E1C
25*2.
CC
CC REL. PERM. EXPONENT OF PHASE 2 AT HIGH CAPILLARY NO.
*----E2C
25*2.
CC
CC REL. PERM. EXPONENT OF PHASE 3 AT HIGH CAPILLARY NO.
*----E3C
25*2.
CC
CC WATER AND OIL VISCOSITY
*----VIS1 VIS2
0.42 1.2
CC
CC VISCOSITY PARAMETERS
*----ALPHA1 ALPHA2 ALPHA3 ALPHA4 ALPHA5
0. 0. 0. .000865 4.153
CC
CC PARAMETERS TO CALCULATE POLYMER VISCOSITY AT ZERO SHEAR RATE
*----AP1 AP2 AP3
81. 2700. 2500.
CC
CC PARAMETER TO COMPUTE CSEP, MIN. CSEP, AND SLOPE OF LOG VIS. VS. LOG CSEP
*----BETAP CSE1 SSLOPE
10. .01 .17
CC
CC PARAMETER FOR SHEAR RATE DEPENDENCE OF POLYMER VISCOSITY
*----GAMMAC GAMHF POWN
20. 10. 1.8
CC
CC FLAG FOR POLYMER INACCESSIBLE PORE VOLUME, PERM. REDUCTION PARAMETERS
*----EPHI4 BRK CRK RKLIM1, RKLIM2

```

```

      1      1. .02 10.      10.1
CC
CC SPECIFIC WEIGHT FOR COMPONENTS 1,2,3, AND GRAVITY FLAG
*----DEN1 DEN2 DEN3 IDEN
      .433 .368 .42 0
CC
CC CAPILLARY PRESSURE PARAMETER, CPC0
*----CPC0
      25*0.
CC
CC CAPILLARY PRESSURE PARAMETER, EPC0
*----EPC0
      25*2.
CC
CC LONGITUDINAL AND TRANSVERSE DISPERSIVITY OF EACH PHASE
*----ALPHAL(1) ALPHAT(1) ALPHAL(2) ALPHAT(2) ALPHAL(3) ALPHAT(3)
      12.      .4      12.      .4      12.      .4
CC
CC SURFACTANT AND POLYMER ADSORPTION PARAMETERS
*----AD31 AD32 B3D AD41 AD42 B4D
      1. .0      1000. 0.7 0.      100.
CC
CC*****
CC
CC WELL DATA
CC
CC*****
CC
CC INJECTION TIME TOLERANCE INI. TIMESTEP, MIN. AND MAX. TIMESTEPS
*----TINJ DCLIM DT DTMIN DTMAX
      10000. 0.001 80. 80. 80.
CC
CC LOCATION, AND FLAG FOR SPECIFYING WELL TYPE, WELL RADIUS
*----IW JW KW IDIR ILTH IFLAG RW
      1 1 1 3 1 1. .5
CC
CC INJ. RATE AND INJ. COMP. OF RATE CONS. WELLS FOR PHASE 1
*---- Q1I (M) C1W(M,KC)
      10000 .995 0. 0.005 0. .65 .133
CC
CC INJ. RATE OF RATE CONS. WELLS FOR PHASE 2
*---- Q2I (M)
      0.
CC
CC INJ. RATE AND INJ. COMP. OF RATE CONS. WELLS FOR PHASE 3
*---- Q3I (M) C1W(M,KC)
      0. .0 0. 0. 0. 0. 0.
CC
CC LOCATION, AND FLAG FOR SPECIFYING WELL TYPE, WELL RADIUS
*----IW JW KW IDIR ILTH IFLAG RW
      5 5 1 3 1 2 .5
CC
CC BOTTOM HOLE PRESSURE FOR PRESSURE CONSTRAINED WELL
*----PWF
      14.7
CC
CC FLAG FOR WRITING SEVERAL PROPERTY PROFILES
*----IP IC IS ICKL IADS IVEL IVIS IPER IRKF IPHSE ICSE
      1 1 1 0 0 0 0 0 0 0 0 0
CC
CC OUTPUT INTERVALS FOR HIST. AND PROF. FILES UNIT FLAG (PV OR DAY)
*---WHDW WPDW INDW
      .01 .5 0

```

Notes:

## 5.0 APPENDIX

The following sections describe: (1) data written to the profile file, (2) data written to the summary file, (3) data written to history files for each well, (4) main program flow outline.

### 5.1 Data Written to Profile Data File (PROF)

The information in the following lists is controlled by the various print control flags in the input files and is printed at each WHDT interval:

- Time
- Cumulative pore volume injected
- Pressure
- Original in place for each component
- Cumulative injection for each component
- Cumulative production for each component
- Amount retained for each component
- Relative error for each component
- Phase saturation of each phase
- Total concentration of each component
- Adsorption
- Phase concentration of each component
- Phase fluxes of each phase
- Phase viscosities of each phase
- Relative permeabilities of each phase
- Permeability reduction
- Phase environment index

## 5.2 Data Written to Summary Data File (SUMA)

Total pore volumes and original amount of each component are first written. The information in the following list is then written at each WHDT interval:

Cumulative pore volume injected, time in days, timestep size, injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ )

For aqueous phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), injection cut, production cut

For oleic phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), Injection cut, production cut, WOR

For microemulsion phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), injection cut, production cut

For each component (units vary depending on component)

Injection rate, cumulative injection, production rate, cumulative production, recovery, injection concentration, production concentration

### 5.3 Data Written to Well History Data Files (HS01-HSNW)

The information in the following list is for each well and printed at each WHDT interval:

Well Number

Cumulative pore volume injected, time in days, cumulative pore volume injected through the well, bottomhole pressure (psia), timestep size, injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ )

For aqueous phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), injection cut, production cut

For oleic phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), Injection cut, production cut, WOR

For microemulsion phase:

Injection rate ( $\text{ft}^3/\text{day}$ ), cumulative injection ( $\text{ft}^3$ ), production rate ( $\text{ft}^3/\text{day}$ ), cumulative production ( $\text{ft}^3$ ), injection cut, production cut

For each component (units vary depending on component)

Injection rate, cumulative injection, production rate, cumulative production, recovery, injection concentration, production concentration



## 5.4 Main Program Flow Outline

The following outline represents the basic flow through the main program.

Open files:

Call OPENFI

Read input file:

Call READIN

Set initial values:

$t=t_0$

Call STAJOB

Calculate coefficients for different discretization schemes and grids:

Call GRIDCO

Calculate the constant portions of transmissibilities and well index:

Call TRANS0

Call WELID0

Update time and count iteration numbers:

$t=t+\Delta t$

iter=iter+1

Calculate the phase saturations and phase compositions and their derivatives:

Call PHCOMP

Calculate adsorptions and their derivatives:

Call ADSORP

Calculate phase densities and their derivatives:

Call DENSTY

Calculate phase viscosity, relative permeabilities, permeability reduction and their derivatives:

Call VISREP

Determine flow directions:

Call FLUXDR

Calculate phase transmissibilities:

Call TRANSM

Calculate fluxes:

Call FLUXRT

Calculate flow rate in each well:

Call WELLID

Calculate dispersion coefficients:

Call DISCO1  
Call DISCO2  
Call DISCO3

Calculate mass balances of each component and overall mass balance and derivatives:

Call C1ATDF  
Call CTATDF  
Call C3ATDF  
Call C4ATDF  
Call C5ATDF  
Call C6ATDF

Setup jacobian matrix:  
Call SETUPS

Solve for primary variables:  
Call PRESLV

Update primary variables:  
Call UPDATE

Check the convergency and output results:  
Call SUMARY

Calculate new timestep sizes

Repeat or stop