USER'S GUIDE FOR UTCHEM IMPLICIT (1.0)
A THREE DIMENSIONAL CHEMICAL FLOOD SIMULATOR

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

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

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The University of Texas at Austin
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A Three Dimensional Chemical Flood Simulator

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Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

Jerry Casteel, Project Manager
Bartlesville Project Office
P.O. Box 1398
Bartlesville, OK 74005

Prepared by
The University of Texas at Austin
Austin, Texas 78712

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TABLE OF CONTENTS

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.

Unit Number	File Name	Contents
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.

Parameter	Definition
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 <u>each</u> 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. <u>All</u> of the variables listed in the input description will be read by the program <u>unless otherwise noted</u>; 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 - Tolerence of primary variable iteration errors

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

      DX(I) - Grid size of Ith block in X direction.
         Units: feet

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

      DY(J) - Grid size of Jth block in Y direction.
         Units: feet

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

      DZ(K) - Grid size of Kth block in Z direction.
         Units: feet

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

      ICF(KC) - Flag indicating if KC^{th} component is included in the concentration
         calculations or not.
         Possible Values:
              0 - The KC^{th} component is not included in the calculations
              1 - The KC^{th} 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 × NY × NZ

POR(I) - Porosity of Ith 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 × 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
```

3.2.2   PERMX(I), for I = 1, NX × NY × NZ

PERMX(I) - Permeability of the Ith 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 × NY × NZ

PERMY(I) - Permeability of the Ith grid block.

Units: millidarcies = $10^{-3}\ \mu m^2$
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 × NY × NZ

PERMZ(I) - Permeability of the Ith grid block.

Units: millidarcies ($10^{-3}\ \mu m^2$)
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 Ith 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^{th} 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^{th} 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^{th} 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^{th} 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 σ_{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^{th} grid block.
Units: fraction

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

S2RWC(K) - Residual saturation of oleic phase displaced by water at low capillary number for I^{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^{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^{th} grid block.
Units: dimensionless

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

P2RWC(K) - Endpoint relative permeability of oil at low capillary number for I^{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^{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^{th} grid block.
Units: dimensionless

3.3.14 E2W(I), for I = 1, NX × NY × NZ

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

3.3.15 E3W(I), for I = 1, NX × NY × NZ

   E3W(I) - Relative permeability exponent of microemulsion phase at low capillary
         number for I^{th} grid block.
         Units: dimensionless

3.3.16 S1RC(I), for I = 1, NX × NY × NZ

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

3.3.17 S2RC(I), for I = 1, NX × NY × NZ

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

3.3.18 S3RC(I), for I = 1, NX × NY × NZ

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

3.3.19 P1RC(I), for I = 1, NX × NY × NZ

   P1RC(I) - Endpoint relative permeability of water at high capillary number for I^{th} grid
         block.
         Units: dimensionless

3.3.20 P2RC(I), for I = 1, NX × NY × NZ

   P2RC(K) - Endpoint relative permeability of oil at high capillary number for I^{th} grid
         block.
         Units: dimensionless

3.3.21 P3RC(I), for I = 1, NX × NY × NZ

   P3RC(I) - Endpoint relative permeability of microemulsion at high capillary number
         for I^{th} grid block.
         Units: dimensionless

3.3.22 E1C(I), for I = 1, NX × NY × NZ

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

3.3.23 E2C(I), for I = 1, NX × NY × NZ

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

3.3.24 E3C(I), for I = 1, NX × NY × NZ

  E3C(I) - Relative permeability exponent of microemulsion phase at high capillary
      number for I^{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: $(wt. \%)^{-1}$, $(wt. \%)^{-2}$, $(wt. \%)^{-3}$

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

GAMHF - Shear rate at which polymer viscosity is one half polymer viscosity at zero shear rate.
Units: 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: $\dfrac{volume\ of\ polymer - rich\ phase}{weight\%\ polymer}$

CRK - Parameter for calculating permeability reduction factor.
Units: $(darcy)^{1/2}\ (100\ g/g)^{-1/3}$

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^3)

3.3.32   CPC(I), for I = 1, NX × NY × NZ

      CPC(I) - Capillary pressure endpoint for I^{th} gridblock.
           Units: psi·$\sqrt{darcies}$

3.3.33   EPC(I), for I = 1, NX × NY × NZ

      EPC(I) - Capillary pressure exponent for I^{th} gridblock.
           Units: dimensionless

      Note: The value for EPC(I) <u>must</u> 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: $\dfrac{\text{volume of water}}{\text{weight\% polymer}}$

Notes:

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 Mth well.
Possible Values: Between 1 and NX

JW(M) - First y-index of the gridblocks containing the Mth well.
Possible Values: Between 1 and NY

KW(M) - First z-index of the gridblocks containing the Mth well.
Possible Values: Between 1 and NZ

IDIR(M) - Flag indicating the direction in which the Mth 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 Mth well.
Possible Values: Between 1 and the number of gridblocks in well direction

IFLAG(M) - Flag indicating type of well constraint specification for M^{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 Mth 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):
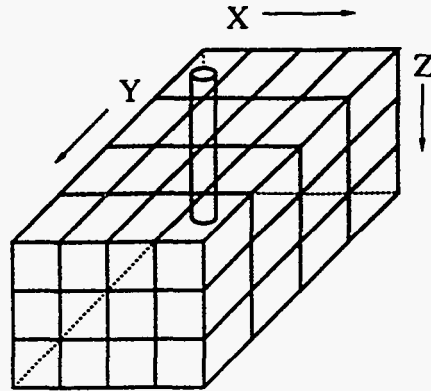
IDIR(M) = 3
IW(M) = 1
JW(M) = 1
KW(M) = 1
ILTH(M) = 3

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):
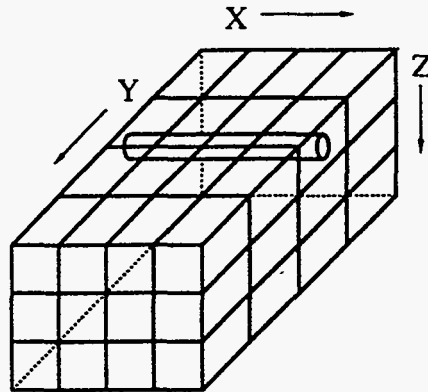
IDIR(M) = 1
IW(M) = 1
JW(M) = 2
KW(M) = 1
ILTH(M) = 4

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^{th} well
     Units: ft^3/day

CQ1(K) - Concentration of Kth component in aqueous phase in M^{th} 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^{th} well
       Units: ft^3/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^{th} well
       Units: ft^3/day

     CQ3(K) - Concentration of Kth component in microemulsion phase in M^{th} 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 Mth 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^{th} well
       Units: fraction

     CQ1(K) - Concentration of Kth component in aqueous phase in M^{th} 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^{th} 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^{th} well
       Units: fraction

     CQ3(K) - Concentration of Kth component in microemulsion phase in M^{th} 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 Mth well.
       Units: psia

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

Q(M) - Total production rate for M[th] well.
   Units: ft^3/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, WPDT,INDW

WHDT - Output intervals of production histories
  Units: pore volumes or days (dependent on flag INDW)

WPDT - 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 TOLERENCE  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
CC  CONSTANT GRID BLOCK SIZE IN Z DIRECTION
*----DZ1
     100
CC
CC FLAG INDICATING IF THE COMPONENT IS INCLUDED IN CALCULATIONS OR NOT
*----ICF(KC) FOR KC=1,NC
     1  1  1  1  1
CC
CC*****************************************************************
CC                                                               *
CC     RESERVOIR PROPERTIES                                      *
CC                                                               *
CC*****************************************************************
CC
CC
CC POROSITY
*----PORC1
     25*.2
CC
CC X-PERMEABILITY (MILIDARCY)
*----PERMX
     25*200
CC
CC Y-PERMEABILITY (MILIDARCY)
*----PERMY
     25*200
CC
CC Z-PERMEABILITY  (MILIDARCY)
*----PERMZ
     25*200.
CC
CC FLAG FOR CONSTANT OR VARIABLE DEPTH, DIP ANGLES
*----IDEPTH  THETAX  THETAY
       0       0       0
CC
CC CONSTANT DEPTH (FT)
*----D111
       0.
CC
CC INITIAL PRESSURE (PSIA)
*----PRESS1
     25*14.7
CC
CC INITIAL WATER CONCENTRATION
*----C1
     25*.45
CC
CC INITIAL SURFACTANT CONCENTRATION
*----C3
     25*0.
CC
CC INITIAL POLYMER CONCENTRATION
*----C4
     25*0.
CC
CC CHLORIDE CONCENTRATIONS (MEQ/ML)
*----C50
     25*.65
CC
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
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 PROFILS
*----IP IC IS ICKL IADS IVEL IVIS IPER  IRKF IPHSE ICSE
     1  1  1  0    0    0    0    0     0    0     0
CC
CC OUTPUT INTERVALS FOR HIST. AND PROF. FILES  UNIT FLAG (PV OR DAY)
*--WHDT WPDT INDW
   .01  .5   0
```

Notes:

5.0   **APPENDIX**

The following sections describe: (1) data written to the profile file, (2) data written to the sumary 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 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 oncentration 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 (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3)

For aqueous phase:

Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3), injection cut, production cut

For oleic phase:

Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3), Injection cut, production cut, WOR

For microemulsion phase:

Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (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 (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3)
For aqueous phase:
Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3), injection cut, production cut
For oleic phase:
Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (ft^3), Injection cut, production cut, WOR
For microemulsion phase:
Injection rate (ft^3/day), cumulative injection (ft^3), production rate (ft^3/day), cumulative production (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 derivities:
    Call PHCOMP

Calculate adsorptions and their derivities:
    Call ADSORP

Calculate phase densitys and their derivities:
    Call DENSTY

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