The Conversion IMEX → STARS.

MODEL

Our model has 3 components, the water component (denoted 'Water'), the dead oil component ('DeadOil'), and the solution gas ('SolGas').

Hence,
ncomp = 3 Total number of components
numy = 3 Total number of components in fluid phases (water, oil, gas)
numx = 3 Total number of components in liquid phases (water, oil)
numw = 1 Number of aqueous components (water)

The **MODEL** keyword has syntax

```
MODEL  ncomp numy numx numw,      for our example
MODEL  3 3 3 1
```

Component names must be supplied:
```
COMPNAME  'Water'  'DeadOil'  'SolGas'
```

Note that many later keywords require component parameters in the *same order* as defined in the COMPNAME keyword.

MOLECULAR WEIGHT

Defined by keyword CMM:
CMM cmm_1 … cmm_{ncomp}

Molecular weights are given mass/mole.

Water has a molecular weight of 0.01802 kg/gmole
As both oil and gas in our example are pseudo-components (not pure components), the calculation or estimation of molecular weights can be somewhat arbitrary. Based on STARS suggestion of some standard values for gases and light – medium – heavy oils, the following values were chosen:
Molecular weight oil: 0.15; gas: 0.022

So the keyword we used was:

```
CMM 0.018 0.15 0.022
```

MASS DENSITY

Density can be given in several ways. For me it was easiest to stick with my existing understanding of density, and just copy over the numbers from the IMEX data set (if the other parameters are OK, STARS will then perform the conversion to mole densities itself).
The keyword MASSDEN allows standard densities at reference pressure and temperature:
```
MASSDEN 1038.0  883.0  0.66
```

K-values, Compressibilities

Now it begins to get a little tricky…

I'll use superscript ST for standard conditions, RC for reservoir conditions (and standard symbols).

From the black oil model we had the parameters:

$\rho_w^{ST} = 1038$ $\rho_o^{ST} = 883$ $\rho_g^{ST} = 0.66$

$B_o(p_{bp}) = 1.2601$ $B_w = 1.024$ $B_g(p_{bp}) = 0.006$ $R_s(p_{bp}) = 80$

$C_w = 4.64E\text{-}7$

$\mu_o(p_{bp}) = 1.041$ $\mu_g(p_{bp}) = 0.015$ $\mu_w = 0.42$

$M_2 = 0.15$ Molecular weight dead-oil component
$M_3 = 0.022$ Molecular weight solution gas component

Then, following the step-by-step description in STARS manual appendix D.18:

moles dead-oil: $mole^{oil} = \frac{\rho_o^{ST}}{M_2 B_o(p_{bp})} = \frac{883}{0.15 \cdot 1.2601} = 4671.587$

moles solution gas: $mole^{gas} = \frac{R_s(p_{bp})\rho_g^{ST}}{M_3 B_o(p_{bp})} = \frac{80 \cdot 0.66}{0.022 \cdot 1.2601} = 1904.61$

oil mole fraction: $x_3 = \frac{R_s \cdot \rho_g^{ST}/M_3}{\frac{\rho_o^{ST}}{M_2} + \frac{R_s \cdot \rho_g^{ST}}{M_3}} = \frac{80 \cdot 0.66/0.022}{\frac{883}{0.15} + \frac{80 \cdot 0.66}{0.022}} = \frac{2400}{5886.667 + 2400} = 0.028962$

and as $x_2 + x_3 = 1$; $x_2 = 0.71038$

Density in a black oil model refers to the density of the *phase* in question. Hence "oil" density will have a strong dependency on the amount of dissolved gas in it.
In contrast, STARS uses *component* mole density, so that oil density refers to the liquid oil, which will typically be much larger, and have a smaller variation, than the black oil variant. (The total density of a phase is computed by STARS from the component values.)
For *live oil*, ref. Eqs. (3-4) in STARS manual appendix D.18.

The *component mole density* for dead oil is $\rho_{o2}^{ST} = \frac{\rho_o^{ST}}{M_2} = 5886.67$

The corresponding value for gas is a bit more tricky, ρ_{o3}^{ST} is the mole density (at some reference pressure p_r) of the solution gas dissolved in oil. This is *not* the density of pure liquid gas, nor is it the gas phase density, or the bulk density of solution gas in the live oil. Actually, it's a quantity that can't be measured, only calculated, by the formula

$$\rho_{o3}^{ST} = \frac{R_s(p_{bp})\rho_g^{ST}/M_3}{\left\{\frac{B_o(p_{bp})/B_o(p_r)}{\exp[C_{o2}(p_{bp} - p_r)]} - 1\right\}}$$

Here C_{o2} is the oil phase compressibility of component 2, the dead oil component.

ρ_{o3}^{ST} is not unique (depends on $B_o(p_r)$), but only one value can be given to STARS, so have to choose some representative value. I didn't manage to compute a sensible value from this (easier for live oil…), so left it as a sensitivity parameter for the time being.

K-values

Recall the K-values we are interested in are the ratios between gas mole fraction and liquid mole fraction:

$K_i = y_i / x_i$

Water and dead oil components don't vaporize significantly, hence $y_1 = y_2 = 0 \leftrightarrow K_1 = K_2 = 0$.
And as $y_1 + y_2 + y_3 = 1$, $y_3 = 1 = K_3 x_3$; hence $K_3(p_{bp}) = 1/x_3$.
Using formulas above the general expression for K_3 becomes,

$$K_3(p) = 1 + \frac{\rho_o^{ST}/M_2}{R_s(p)\rho_g^{ST}/M_3} = 1 + \frac{5886.67}{2400} = 3.4528$$

Computing of compressibilities

This was an uncertain task.

First computed oil (phase) density by the standard definition of B_o:

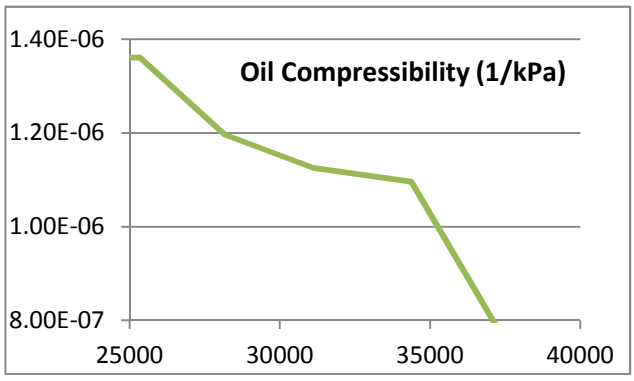
$$\rho_o^{RC} = \frac{\rho_o^{ST} + R_s\rho_g^{ST}}{B_o(p)} = \frac{833 + 80 \cdot 0.66}{B_o(p)}$$

Then computed compressibility by standard definition:

$$C_o = \frac{1}{\rho(p)} \cdot \frac{\Delta\rho}{\Delta p}$$

The variation of B_o with p from the IMEX (ECLIPSE) simulation, and computed values from formulas above:

p	B_o	ρ_o	C_o
22700	1.2601	703.01	1.358E-6
25340	1.2555	705.54	1.361E-6
28160	1.2507	708.24	1.197E-6
31110	1.2463	710.74	1.125E-6
34380	1.2417	713.36	1.096E-6
37350	1.2377	715.68	7.725E-7
39550	1.2356	716.90	



Used a "conservative" value of C_o = 1.0E-7 in the data file.

An estimate of the gas compressibility, which is the big uncertain factor here, naïve and simple

$$C_g = \frac{\left\{\frac{1 - B_g(p_{bp})}{p_{bp} - p^{ST}}\right\}}{B_g(p_{bp})} = 0.009255$$

By that, most of the hard work is done, and we can add the following keywords to the data file:

K-values (Water, Dead oil, Solution gas)

```
KV1   0.0   0.0   0.0
KV2   0.0   0.0   0.0
KV3   0.0   0.0   3.4525
KV4   0.0   0.0   0.0
KV5   0.0   0.0   0.0
```

The argument behind setting all KV's for gas to zero, except KV3, was to try to emulate dead oil – constant behavior above bubble point, thereafter only surface conditions are interesting. (I don't say that's correct thinking – it isn't – but it's how I reasoned to define the table)

Liquid compressibility CP (water, oil, gas)

```
CP 4.64E-7  1.0E-7  0.00925
```

Thermal expansion coefficient CT1 – not used in this run, so some "standard" values used.

OTHER INPUT

The rest of the input is now relatively straightforward

Keyword **SURFLASH**
This keyword is supposed to enable definition of flash conditions at surface conditions, irrespective of what the K-value computations should deliver. Just what we're after – being able to define the surface GOR equal to the dead oil model. So included the following:

```
SURFLASH SEGREGATED
K_SURF 'DeadOil' 0
K_SURF 'SolGas' 80
```

The section on sensitivities refers how this went; just to reveal it now – didn't work at all…

Viscosity

Didn't do anything special with viscosity, just copied it over from the dead oil PVT tables, adjusting to STARS syntax (one "table" for each temperature, so an isothermal, pressure-dependent table looks a little cumbersome).

```
**   temp   mu_w    mu_o  mu_g
VISCTABLE
ATPRES 18000
     20     0.42   1.041  0.015
ATPRES 22700
     20     0.42   1.042  0.015
ATPRES 25340
     20     0.42   1.072  0.015
ATPRES 28160
     20     0.42   1.096  0.015
ATPRES 31110
     20     0.42   1.118  0.015
ATPRES 34380
     20     0.42   1.151  0.015
ATPRES 37350
     20     0.42   1.174  0.015
ATPRES 39550
     20     0.42   1.2    0.015
```

INITIALISATION

Only special input here is the MFRAC family of keywords, which define the initial mole fractions of the components.
As an initial attempt, set MFRAC for water to 1. As I wanted to set the bubble point pressure explicitly equal to the black-oil case, I tried the PBC keyword. Surprisingly, STARS didn't accept PBC for component 'DeadOil', which is where I thought it belonged. But PBC for 'SolGas' was accepted (but didn't work as expected…)

So the syntax used:

```
MFRAC_WAT   'Water'   CON 1
**MFRAC_OIL 'DeadOil' CON 1
PBC         'SolGas'  CON 22700
```

And wonder of wonders – the data file ran at first attempt! – But the results were disappointing… didn't match the IMEX case at all.