APPENDIX A

DYNAMIC SIMULATION BY MATHCAD PROGRAM

Continuity Equation

$L_{16} = 0$
$L_{15} = 0.0006$
$L_{14} = 0.0006$
$L_{13} = 0.0006$
$L_{12} = 0.0006$
$L_{11} = 0.0006$
$L_{10} = 0.0006$
$L_{9} = 0.0006$
$L_{8} = 0.0006$
$L_{7} = 0.0006$
$L_{6} = 0.0006$
$L_{5} = 0.0018$
$L_{4} = 0.0018$
$L_{3} = 0.0018$
$L_{2} = 0.0018$
$L_{1} = 0.0018$

$FL_{15} = 0$
$FL_{14} = 0$
$FL_{13} = 0$
$FL_{12} = 0$
$FL_{11} = 0$
$FL_{10} = 0$
$FL_{9} = 0$
$FL_{8} = 0$
$FL_{7} = 0$
$FL_{6} = 0$
$FL_{5} = 0.0012$
$FL_{4} = 0$
$FL_{3} = 0$
$FL_{2} = 0$
$FL_{1} = 0$

$FV_{14} = 0$
$FV_{13} = 0$
$FV_{12} = 0$
$FV_{11} = 0$
$FV_{10} = 0$
$FV_{9} = 0$
$FV_{8} = 0$
$FV_{7} = 0$
$FV_{6} = 0$
$FV_{5} = 0$
$FV_{4} = 0$
$FV_{3} = 0$
$FV_{2} = 0$
$FV_{1} = 0$
$FV_{0} = 0$

$V_{15} = 0$
$V_{14} = 0.0013$
$V_{13} = 0.0013$
$V_{12} = 0.0013$
$V_{11} = 0.0013$
$V_{10} = 0.0013$
$V_{9} = 0.0013$
$V_{8} = 0.0013$
$V_{7} = 0.0013$
$V_{6} = 0.0013$
$V_{5} = 0.0013$
$V_{4} = 0.0013$
$V_{3} = 0.0013$
$V_{2} = 0.0013$
$V_{1} = 0.0013$
$V_{0} = 0$

$SL_{15} = 0$
$SL_{14} = 0$
$SL_{13} = 0$
$SL_{12} = 0$
$SL_{11} = 0$
$SL_{10} = 0$
$SL_{9} = 0$
$SL_{8} = 0$
$SL_{7} = 0$
$SL_{6} = 0$
$SL_{5} = 0$
$SL_{4} = 0$
$SL_{3} = 0$
$SL_{2} = 0$
$SL_{1} = 0.0005$

$SV_{15} = 0.0007$
$SV_{14} = 0$
$SV_{13} = 0$
$SV_{12} = 0$
$SV_{11} = 0$
$SV_{10} = 0$
$SV_{9} = 0$
$SV_{8} = 0$
$SV_{7} = 0$
$SV_{6} = 0$
$SV_{5} = 0$
$SV_{4} = 0$
$SV_{3} = 0$
$SV_{2} = 0$
$SV_{1} = 0$

Bubble Point Temp

T_{15} = 87

T_{14} = 99

T_{13} = 105.5

T_{12} = 112

T_{11} = 117.5

T_{10} = 121.3

T_9 = 123.9

T_8 = 125

T_7 = 125.5

T_6 = 126

T_5 = 99

T_4 = 99.5

T_3 = 138

T_2 = 172

T_1 = 180

T_0 = 180

$$Tk_{15} = (273 + T_{15}) \cdot \frac{9}{5} \qquad Tcp_{15} = 273 + T_{15}$$

$$Tk_{14} = (273 + T_{14}) \cdot \frac{9}{5} \qquad Tcp_{14} = 273 + T_{14}$$

$$Tk_{13} = (273 + T_{13}) \cdot \frac{9}{5} \qquad Tcp_{13} = 273 + T_{13}$$

$$Tk_{12} = (273 + T_{12}) \cdot \frac{9}{5} \qquad Tcp_{12} = 273 + T_{12}$$

$$Tk_{11} = (273 + T_{11}) \cdot \frac{9}{5} \qquad Tcp_{11} = 273 + T_{11}$$

$$Tk_{10} = (273 + T_{10}) \cdot \frac{9}{5} \qquad Tcp_{10} = 273 + T_{10}$$

$$Tk_{9} = (273 + T_{9}) \cdot \frac{9}{5} \qquad Tcp_{9} = 273 + T_{9}$$

$$Tk_{8} = (273 + T_{8}) \cdot \frac{9}{5} \qquad Tcp_{8} = 273 + T_{8}$$

$$Tk_{7} = (273 + T_{7}) \cdot \frac{9}{5} \qquad Tcp_{7} = 273 + T_{7}$$

$$Tk_{6} = (273 + T_{6}) \cdot \frac{9}{5} \qquad Tcp_{6} = 273 + T_{6}$$

$$Tk_{5} = (273 + T_{5}) \cdot \frac{9}{5} \qquad Tcp_{5} = 273 + T_{5}$$

$$Tk_{4} = (273 + T_{4}) \cdot \frac{9}{5} \qquad Tcp_{4} = 273 + T_{4}$$

$$Tk_{3} = (273 + T_{3}) \cdot \frac{9}{5} \qquad Tcp_{3} = 273 + T_{3}$$

$$Tk_{2} = (273 + T_{2}) \cdot \frac{9}{5} \qquad Tcp_{2} = 273 + T_{2}$$

$$Tk_{1} = (273 + T_{1}) \cdot \frac{9}{5} \qquad Tcp_{1} = 273 + T_{1}$$

$$Tk_{0} = (273 + T_{0}) \cdot \frac{9}{5} \qquad Tcp_{0} = 273 + T_{0}$$

Equilibrium Constant

$P = 14.7$

$i = 0..6$

$j = 0..15$

C5

$m_0 = -1524891$

$n_0 = 0$

$o_0 = 7.33129$

$p_0 = -0.89143$

$q_0 = 0$

$r_0 = 0$

C6

$m_1 = -1778901$

$n_1 = 0$

$o_1 = 6.96783$

$p_1 = -0.84643$

$q_1 = 0$

$r_1 = 0$

C7

$m_2 = -2013803$

$n_2 = 0$

$o_2 = 6.52914$

$p_2 = -0.79543$

$q_2 = 0$

$r_2 = 0$

C8

$m_3 = 0$

$n_3 = -7646.81641$

$o_3 = 12.48457$

$p_3 = -0.73152$

$q_3 = 0$

$r_3 = 0$

C9

$m_4 = -2551040$

$n_4 = 0$

$o_4 = 5.69313$

$p_4 = -0.67818$

$q_4 = 0$

$r_4 = 0$

C10

$m_5 = 0$

$n_5 = -9760.45703$

$o_5 = 13.80354$

$p_5 = -0.71470$

$q_5 = 0$

$r_5 = 0$

C11

$m_6 = 0$

$n_6 = -9760.45703$

$o_6 = 13.80354$

$p_6 = -0.71470$

$q_6 = 0$

$r_6 = 0$

$$Kc_{i,j} = e^{\frac{m_i}{\left(Tk_j\right)^2} + \frac{n_i}{Tk_j} + o_i + p_i \ln(P) + \frac{q_i}{P^2} + \frac{r_i}{P}}$$

Liquid Composition

C5	C6	C7	C8	C9
$x_{0,15}$ = 0.0175	$x_{1,15}$ = 0.3290	$x_{2,15}$ = 0.5977	$x_{3,15}$ = 0.0534	$x_{4,15}$ = 0
$x_{0,14}$ = 0.0038	$x_{1,14}$ = 0.1627	$x_{2,14}$ = 0.6896	$x_{3,14}$ = 0.1440	$x_{4,14}$ = 0
$x_{0,13}$ = 0.0011	$x_{1,13}$ = 0.0768	$x_{2,13}$ = 0.6390	$x_{3,13}$ = 0.2831	$x_{4,13}$ = 0
$x_{0,12}$ = 0.0006	$x_{1,12}$ = 0.0403	$x_{2,12}$ = 0.5085	$x_{3,12}$ = 0.4507	$x_{4,12}$ = 0
$x_{0,11}$ = 0.0004	$x_{1,11}$ = 0.0259	$x_{2,11}$ = 0.3659	$x_{3,11}$ = 0.6078	$x_{4,11}$ = 0
$x_{0,10}$ = 0.0004	$x_{1,10}$ = 0.0202	$x_{2,10}$ = 0.2544	$x_{3,10}$ = 0.7250	$x_{4,10}$ = 0
$x_{0,9}$ = 0.0004	$x_{1,9}$ = 0.0179	$x_{2,9}$ = 0.1832	$x_{3,9}$ = 0.7986	$x_{4,9}$ = 0
$x_{0,8}$ = 0.0004	$x_{1,8}$ = 0.0170	$x_{2,8}$ = 0.1431	$x_{3,8}$ = 0.8396	$x_{4,8}$ = 0
$x_{0,7}$ = 0.0004	$x_{1,7}$ = 0.0168	$x_{2,7}$ = 0.1224	$x_{3,7}$ = 0.8604	$x_{4,7}$ = 0
$x_{0,6}$ = 0.0004	$x_{1,6}$ = 0.0169	$x_{2,6}$ = 0.1129	$x_{3,6}$ = 0.8699	$x_{4,6}$ = 0
$x_{0,5}$ = 0.0054	$x_{1,5}$ = 0.1897	$x_{2,5}$ = 0.5967	$x_{3,5}$ = 0.1065	$x_{4,5}$ = 0.0513
$x_{0,4}$ = 0.0055	$x_{1,4}$ = 0.1915	$x_{2,4}$ = 0.5987	$x_{3,4}$ = 0.1050	$x_{4,4}$ = 0.0507
$x_{0,3}$ = 0.0005	$x_{1,3}$ = 0.0376	$x_{2,3}$ = 0.2562	$x_{3,3}$ = 0.1184	$x_{4,3}$ = 0.2090
$x_{0,2}$ = 0	$x_{1,2}$ = 0.0032	$x_{2,2}$ = 0.0460	$x_{3,2}$ = 0.0520	$x_{4,2}$ = 0.2165
$x_{0,1}$ = 0	$x_{1,1}$ = 0.0003	$x_{2,1}$ = 0.0071	$x_{3,1}$ = 0.0214	$x_{4,1}$ = 0.1580
$x_{0,0}$ = 0	$x_{1,0}$ = 0.0003	$x_{2,0}$ = 0.0071	$x_{3,0}$ = 0.0214	$x_{4,0}$ = 0.1580

C10	C11
$x_{5,15} = 0$	$x_{6,15} = 0$
$x_{5,14} = 0$	$x_{6,14} = 0$
$x_{5,13} = 0$	$x_{6,13} = 0$
$x_{5,12} = 0$	$x_{6,12} = 0$
$x_{5,11} = 0$	$x_{6,11} = 0$
$x_{5,10} = 0$	$x_{6,10} = 0$
$x_{5,9} = 0$	$x_{6,9} = 0$
$x_{5,8} = 0$	$x_{6,8} = 0$
$x_{5,7} = 0$	$x_{6,7} = 0$
$x_{5,6} = 0$	$x_{6,6} = 0$
$x_{5,5} = 0.0375$	$x_{6,5} = 0.0129$
$x_{5,4} = 0.0362$	$x_{6,4} = 0.0124$
$x_{5,3} = 0.2816$	$x_{6,3} = 0.0967$
$x_{5,2} = 0.5079$	$x_{6,2} = 0.1745$
$x_{5,1} = 0.6052$	$x_{6,1} = 0.2079$
$x_{5,0} = 0.6052$	$x_{6,0} = 0.2079$

$$\Sigma y_j = 1$$

$$y_j = \sum_i Kc_{i,j} \cdot x_{i,j}$$

Vapor Component

$$a_{i,j} = Kc_{i,j} \cdot x_{i,j}$$

Heat Capacity and Heat of Vaporization

C_5

$s = 4.895$

$u = 90113$

$w = 28039000$

$$Cp_{i,j} = s + u \cdot Tcp_j + w \cdot (Tcp_j)^2$$

$l_{15} = 65$

$l_{14} = 66$

$l_{13} = 67$

$l_{12} = 67$

$l_{11} = 69$

$l_{10} = 70$

$l_9 = 71$

$l_8 = 71$

$l_7 = 71.5$

$l_6 = 71.5$

$l_5 = 72$

$l_4 = 73$

$l_3 = 74$

$l_2 = 74$

$l_1 = 75$

$l_0 = 75$

Enthalpy of vapor

$$b_j = a_{0,j} Cp_{0,j} (Tcp_j - 25) + a_{1,j} Cp_{1,j} (Tcp_j - 25) + a_{2,j} Cp_{2,j} (Tcp_j - 25) + a_{3,j} Cp_{3,j} (Tcp_j - 25) - a_{4,j} Cp_{4,j} (Tcp_j - 25) + a_{5,j} Cp_{5,j} (Tcp_j - 25) - a_{6,j} Cp_{6,j} (Tcp_j - 25)$$

Initial Guess

Y =

0.0175 For X_n
0.0036
0.0008
0.0002
0.0001
0.0001
0.0001
0.0001
0.0001
0.0001
0.0053
0.0054
0.0005
0.0005
0.0005
1.38510^{11} For h_n
3.73310^{10}
1.27610^{10}
6.90210^{9}
4.28410^{9}
3.17710^{9}
3.21110^{9}
3.23110^{9}
3.24510^{9}
3.24810^{9}
5.40110^{10}
5.82610^{10}
1.17310^{10}
0
0
0.052063 For M_n
0.04933
0.043836
0.037225
0.035491
0.035256
0.035228
0.035453
0.035238
0.035244
0.04856
0.048626
0.04001
0.03611
0.035137

Weir Length 2.133 ft
Weir Height 0.0656 ft (2cm)

$$D(L,Y) := \begin{pmatrix}
\frac{(L_{16} Y_0 + FL_{15} Y_1 + FV_{14} a_{0,14} + V_{14} a_{0,14} - V_{15} a_{0,15} - L_{15} Y_1 - SL_{15} Y_1 - SV_{15} a_{0,15}) - (L_{16} + FL_{15} + FV_{14} + V_{14} - V_{15} - L_{15} - SL_{15} - SV_{15}) Y_1}{Y_{30}} \\
\frac{(L_{15} Y_1 + FL_{14} Y_2 + FV_{13} a_{0,13} + V_{13} a_{0,13} - V_{14} a_{0,14} - L_{14} Y_2 - SL_{14} Y_2 - SV_{14} a_{0,14}) - (L_{15} + FL_{14} + FV_{13} + V_{13} - V_{14} - L_{14} - SL_{14} - SV_{14}) Y_2}{Y_{31}} \\
\frac{(L_{14} Y_2 + FL_{13} Y_3 + FV_{12} a_{0,12} + V_{12} a_{0,12} - V_{13} a_{0,13} - L_{13} Y_3 - SL_{13} Y_3 - SV_{13} a_{0,13}) - (L_{14} + FL_{13} + FV_{12} + V_{12} - V_{13} - L_{13} - SL_{13} - SV_{13}) Y_3}{Y_{32}} \\
\frac{(L_{13} Y_3 + FL_{12} Y_4 + FV_{11} a_{0,11} + V_{11} a_{0,11} - V_{12} a_{0,12} - L_{12} Y_4 - SL_{12} Y_4 - SV_{12} a_{0,12}) - (L_{13} + FL_{12} + FV_{11} + V_{11} - V_{12} - L_{12} - SL_{12} - SV_{12}) Y_4}{Y_{33}} \\
\frac{(L_{12} Y_4 + FL_{11} Y_5 + FV_{10} a_{0,10} + V_{10} a_{0,10} - V_{11} a_{0,11} - L_{11} Y_5 - SL_{11} Y_5 - SV_{11} a_{0,11}) - (L_{12} + FL_{11} + FV_{10} + V_{10} - V_{11} - L_{11} - SL_{11} - SV_{11}) Y_5}{Y_{34}} \\
\frac{(L_{11} Y_5 + FL_{10} Y_6 + FV_9 a_{0,9} + V_9 a_{0,9} - V_{10} a_{0,10} - L_{10} Y_6 - SL_{10} Y_6 - SV_{10} a_{0,10}) - (L_{11} + FL_{10} + FV_9 + V_9 - V_{10} - L_{10} - SL_{10} - SV_{10}) Y_6}{Y_{35}} \\
\frac{(L_{10} Y_6 + FL_9 Y_7 + FV_8 a_{0,8} + V_8 a_{0,8} - V_9 a_{0,9} - L_9 Y_7 - SL_9 Y_7 - SV_9 a_{0,9}) - (L_{10} + FL_9 + FV_8 + V_8 - V_9 - L_9 - SL_9 - SV_9) Y_7}{Y_{36}} \\
\frac{(L_9 Y_7 + FL_8 Y_8 + FV_7 a_{0,7} + V_7 a_{0,7} - V_8 a_{0,8} - L_8 Y_8 - SL_8 Y_8 - SV_8 a_{0,8}) - (L_9 + FL_8 + FV_7 + V_7 - V_8 - L_8 - SL_8 - SV_8) Y_8}{Y_{37}} \\
\frac{(L_8 Y_8 + FL_7 Y_9 + FV_6 a_{0,6} + V_6 a_{0,6} - V_7 a_{0,7} - L_7 Y_9 - SL_7 Y_9 - SV_7 a_{0,7}) - (L_8 + FL_7 + FV_6 + V_6 - V_7 - L_7 - SL_7 - SV_7) Y_9}{Y_{38}} \\
\frac{(L_7 Y_9 + FL_6 Y_{10} + FV_5 a_{0,5} + V_5 a_{0,5} - V_6 a_{0,6} - L_6 Y_{10} - SL_6 Y_{10} - SV_6 a_{0,6}) - (L_7 + FL_6 + FV_5 + V_5 - V_6 - L_6 - SL_6 - SV_6) Y_{10}}{Y_{39}} \\
\frac{(L_6 Y_{10} + FL_5 Y_{11} + FV_4 a_{0,4} + V_4 a_{0,4} - V_5 a_{0,5} - L_5 Y_{11} - SL_5 Y_{11} - SV_5 a_{0,5}) - (L_6 + FL_5 + FV_4 + V_4 - V_5 - L_5 - SL_5 - SV_5) Y_{11}}{Y_{40}} \\
\frac{(L_5 Y_{11} + FL_4 Y_{12} + FV_3 a_{0,3} + V_3 a_{0,3} - V_4 a_{0,4} - L_4 Y_{12} - SL_4 Y_{12} - SV_4 a_{0,4}) - (L_5 + FL_4 + FV_3 + V_3 - V_4 - L_4 - SL_4 - SV_4) Y_{12}}{Y_{41}} \\
\frac{(L_4 Y_{12} + FL_3 Y_{13} + FV_2 a_{0,2} + V_2 a_{0,2} - V_3 a_{0,3} - L_3 Y_{13} - SL_3 Y_{13} - SV_3 a_{0,3}) - (L_4 + FL_3 + FV_2 + V_2 - V_3 - L_3 - SL_3 - SV_3) Y_{13}}{Y_{42}} \\
\frac{(L_3 Y_{13} + FL_2 Y_{14} + FV_1 a_{0,1} + V_1 a_{0,1} - V_2 a_{0,2} - L_2 Y_{14} - SL_2 Y_{14} - SV_2 a_{0,2}) - (L_3 + FL_2 + FV_1 + V_1 - V_2 - L_2 - SL_2 - SV_2) Y_{14}}{Y_{43}} \\
\frac{(L_2 Y_{14} + FL_1 Y_{15} + FV_0 a_{0,0} + V_0 a_{0,0} - V_1 a_{0,1} - L_1 Y_{15} - SL_1 Y_{15} - SV_1 a_{0,1}) - (L_2 + FL_1 + FV_0 + V_0 - V_1 - L_1 - SL_1 - SV_1) Y_{15}}{Y_{44}} \\
\frac{(L_{16} Y_{15} + FL_{15} Y_{16} + FV_{14} h_{14} + V_{14} h_{14} - V_{15} h_{15} - L_{15} Y_{16} - SL_{15} Y_{16} - SV_{15} h_{15}) - (L_{16} + FL_{15} + FV_{14} + V_{14} - V_{15} - L_{15} - SL_{15} - SV_{15}) Y_{15}}{Y_{30}} - 4.6 \cdot 10^{7} \\
\frac{(L_{15} Y_{16} + FL_{14} Y_{17} + FV_{13} h_{13} + V_{13} h_{13} - V_{14} h_{14} - L_{14} Y_{17} - SL_{14} Y_{17} - SV_{14} h_{14}) - (L_{15} + FL_{14} + FV_{13} + V_{13} - V_{14} - L_{14} - SL_{14} - SV_{14}) Y_{16}}{Y_{31}} \\
\frac{(L_{14} Y_{17} + FL_{13} Y_{18} + FV_{12} h_{12} + V_{12} h_{12} - V_{13} h_{13} - L_{13} Y_{18} - SL_{13} Y_{18} - SV_{13} h_{13}) - (L_{14} + FL_{13} + FV_{12} + V_{12} - V_{13} - L_{13} - SL_{13} - SV_{13}) Y_{17}}{Y_{32}} \\
\frac{(L_{13} Y_{18} + FL_{12} Y_{19} + FV_{11} h_{11} + V_{11} h_{11} - V_{12} h_{12} - L_{12} Y_{19} - SL_{12} Y_{19} - SV_{12} h_{12}) - (L_{13} + FL_{12} + FV_{11} + V_{11} - V_{12} - L_{12} - SL_{12} - SV_{12}) Y_{18}}{Y_{33}} \\
\frac{(L_{12} Y_{19} + FL_{11} Y_{20} + FV_{10} h_{10} + V_{10} h_{10} - V_{11} h_{11} - L_{11} Y_{20} - SL_{11} Y_{20} - SV_{11} h_{11}) - (L_{12} + FL_{11} + FV_{10} + V_{10} - V_{11} - L_{11} - SL_{11} - SV_{11}) Y_{19}}{Y_{34}} \\
\frac{(L_{11} Y_{20} + FL_{10} Y_{21} + FV_9 h_9 + V_9 h_9 - V_{10} h_{10} - L_{10} Y_{21} - SL_{10} Y_{21} - SV_{10} h_{10}) - (L_{11} + FL_{10} + FV_9 + V_9 - V_{10} - L_{10} - SL_{10} - SV_{10}) Y_{20}}{Y_{35}} \\
\frac{(L_{10} Y_{21} + FL_9 Y_{22} + FV_8 h_8 + V_8 h_8 - V_9 h_9 - L_9 Y_{22} - SL_9 Y_{22} - SV_9 h_9) - (L_{10} + FL_9 + FV_8 + V_8 - V_9 - L_9 - SL_9 - SV_9) Y_{21}}{Y_{36}} \\
\frac{(L_9 Y_{22} + FL_8 Y_{23} + FV_7 h_7 + V_7 h_7 - V_8 h_8 - L_8 Y_{23} - SL_8 Y_{23} - SV_8 h_8) - (L_9 + FL_8 + FV_7 + V_7 - V_8 - L_8 - SL_8 - SV_8) Y_{22}}{Y_{37}} \\
\frac{(L_8 Y_{23} + FL_7 Y_{24} + FV_6 h_6 + V_6 h_6 - V_7 h_7 - L_7 Y_{24} - SL_7 Y_{24} - SV_7 h_7) - (L_8 + FL_7 + FV_6 + V_6 - V_7 - L_7 - SL_7 - SV_7) Y_{23}}{Y_{38}} \\
\frac{(L_7 Y_{24} + FL_6 Y_{25} + FV_5 h_5 + V_5 h_5 - V_6 h_6 - L_6 Y_{25} - SL_6 Y_{25} - SV_6 h_6) - (L_7 + FL_6 + FV_5 + V_5 - V_6 - L_6 - SL_6 - SV_6) Y_{24}}{Y_{39}} \\
\frac{(L_6 Y_{25} + FL_5 Y_{26} + FV_4 h_4 + V_4 h_4 - V_5 h_5 - L_5 Y_{26} - SL_5 Y_{26} - SV_5 h_5) - (L_6 + FL_5 + FV_4 + V_4 - V_5 - L_5 - SL_5 - SV_5) Y_{25}}{Y_{40}} \\
\frac{(L_5 Y_{26} + FL_4 Y_{27} + FV_3 h_3 + V_3 h_3 - V_4 h_4 - L_4 Y_{27} - SL_4 Y_{27} - SV_4 h_4) - (L_5 + FL_4 + FV_3 + V_3 - V_4 - L_4 - SL_4 - SV_4) Y_{26}}{Y_{41}} \\
\frac{(L_4 Y_{27} + FL_3 Y_{28} + FV_2 h_2 + V_2 h_2 - V_3 h_3 - L_3 Y_{28} - SL_3 Y_{28} - SV_3 h_3) - (L_4 + FL_3 + FV_2 + V_2 - V_3 - L_3 - SL_3 - SV_3) Y_{27}}{Y_{42}} \\
\frac{(L_3 Y_{28} + FL_2 Y_{29} + FV_1 h_1 + V_1 h_1 - V_2 h_2 - L_2 Y_{29} - SL_2 Y_{29} - SV_2 h_2) - (L_3 + FL_2 + FV_1 + V_1 - V_2 - L_2 - SL_2 - SV_2) Y_{28}}{Y_{43}} \\
\frac{(L_2 Y_{29} + FL_1 Y_{30} + FV_0 h_0 + V_0 h_0 - V_1 h_1 - L_1 Y_{30} - SL_1 Y_{30} - SV_1 h_1) - (L_2 + FL_1 + FV_0 + V_0 - V_1 - L_1 - SL_1 - SV_1) Y_{29}}{Y_{44}} - 8.672 \cdot 10^{11} \\
L_{16} + FL_{15} + FV_{14} + V_{14} - V_{15} - L_{15} - SL_{15} - SV_{15} \\
L_{15} + FL_{14} + FV_{13} + V_{13} - V_{14} - L_{14} - SL_{14} - SV_{14} \\
L_{14} + FL_{13} + FV_{12} + V_{12} - V_{13} - L_{13} - SL_{13} - SV_{13} \\
L_{13} + FL_{12} + FV_{11} + V_{11} - V_{12} - L_{12} - SL_{12} - SV_{12} \\
L_{12} + FL_{11} + FV_{10} + V_{10} - V_{11} - L_{11} - SL_{11} - SV_{11} \\
L_{11} + FL_{10} + FV_9 + V_9 - V_{10} - L_{10} - SL_{10} - SV_{10} \\
L_{10} + FL_9 + FV_8 + V_8 - V_9 - L_9 - SL_9 - SV_9 \\
L_9 + FL_8 + FV_7 + V_7 - V_8 - L_8 - SL_8 - SV_8 \\
L_8 + FL_7 + FV_6 + V_6 - V_7 - L_7 - SL_7 - SV_7 \\
L_7 + FL_6 + FV_5 + V_5 - V_6 - L_6 - SL_6 - SV_6 \\
L_6 + FL_5 + FV_4 + V_4 - V_5 - L_5 - SL_5 - SV_5 \\
L_5 + FL_4 + FV_3 + V_3 - V_4 - L_4 - SL_4 - SV_4 \\
L_4 + FL_3 + FV_2 + V_2 - V_3 - L_3 - SL_3 - SV_3 \\
L_3 + FL_2 + FV_1 + V_1 - V_2 - L_2 - SL_2 - SV_2 \\
L_2 + FL_1 + FV_0 + V_0 - V_1 - L_1 - SL_1 - SV_1
\end{pmatrix}$$

$$Q_{condenser} := 4.6 \cdot 10^{7}$$

$$Q_{reboiler} := 8.672 \cdot 10^{11}$$

$$Z(L,Y) := rkfixed(Y, 0, 3, 1, D)$$

APPENDIX B
MULTICOMPONENT DISTILLATION CALCULATION

Operating condition :	Pressure	14.7	psia
	Feed inlet temperature	125	^{0}C
	Product output temperature	79.5	^{0}C
	Bottom output temperature	114.3	^{0}C
	Feed flowrate	45	GPM
	Distillate (Rubber Solvent)	3.9	GPM
	Reflux feed rate	21.7	GPM

Multicomponent Distillation Calculation for Vapor Phase

Tray (j)	$y_{C5,j-1}$	$y_{C6,j-1}$	$y_{C7,j-1}$	$y_{C8,j-1}$	$y_{C9,j-1}$	$y_{C10,j-1}$	$y_{C11,j-1}$
15	0.0345	0.3177	0.5309	0.1117	0.0023	0.0016	0.0004
14	0.0104	0.1609	0.5330	0.2531	0.0127	0.0239	0.0060
13	0.0061	0.0801	0.3319	0.3086	0.0372	0.1888	0.0472
12	0.0054	0.0540	0.1355	0.1395	0.0375	0.5024	0.1256
11	0.0053	0.0502	0.0918	0.0438	0.0184	0.6323	0.1581
10	0.0053	0.0499	0.0872	0.0241	0.0078	0.6604	0.1651
9	0.0053	0.0499	0.0869	0.0209	0.0035	0.6667	0.1667
8	0.0053	0.0499	0.0871	0.0204	0.0018	0.6683	0.1671
7	0.0053	0.0500	0.0873	0.0204	0.0011	0.6686	0.1672
6	0.0053	0.0501	0.0875	0.0205	0.0008	0.6685	0.1671
5	0.0490	0.3835	0.4791	0.0761	0.0085	0.0029	0.0009
4	0.0096	0.1648	0.4660	0.1877	0.0872	0.0644	0.0202
3	0.0009	0.0290	0.1787	0.1761	0.2116	0.3072	0.0965
2	0.0002	0.0040	0.0344	0.0833	0.1974	0.5179	0.1628
1	0.0002	0.0024	0.0130	0.0495	0.1454	0.6006	0.1889

Multicomponent Distillation Calculation for Liquid Phase

Tray (j)	$x_{C5,j}$	$x_{C6,j}$	$x_{C7,j}$	$x_{C8,j}$	$x_{C9,j}$	$x_{C10,j}$	$x_{C11,j}$
15	0.0345	0.3177	0.5309	0.1117	0.0023	0.0016	0.0004
14	0.0061	0.1327	0.5334	0.2785	0	0.0279	0
13	0.0010	0.0374	0.2961	0.3440	0.0434	0.2224	0.0556
12	0.0002	0.0066	0.0644	0.1445	0.0438	0.5924	0.1481
11	0.0001	0.0022	0.0129	0.0315	0.0213	0.7456	0.1864
10	0.0001	0.0018	0.0075	0.0084	0.0088	0.7788	0.1947
9	0.0001	0.0018	0.0071	0.0046	0.0037	0.7862	0.1965
8	0.0001	0.0018	0.0073	0.0040	0.0017	0.7881	0.1970
7	0.0001	0.0019	0.0076	0.0040	0.0009	0.7885	0.1971
6	0.0001	0.0020	0.0079	0.0041	0.0005	0.7884	0.1971
5	0.0106	0.1849	0.5221	0.1803	0.0503	0.0395	0.0123
4	0.0108	0.1868	0.5242	0.1782	0.0497	0.0383	0.0119
3	0.0008	0.0308	0.1942	0.1649	0.1926	0.3171	0.0995
2	0.0000	0.0021	0.0285	0.0583	0.1763	0.5591	0.1757
1	0.0000	0.0002	0.0039	0.0195	0.1166	0.6541	0.2056

Operating condition :	Pressure	14.7	psia
	Feed inlet temperature	130	^{O}C
	Product output temperature	82.6	^{O}C
	Bottom output temperature	118.9	^{O}C
	Feed flowrate	45	GPM
	Distillate (Rubber Solvent)	3.9	GPM
	Reflux feed rate	21.7	GPM

Multicomponent Distillation Calculation for Vapor Phase

Tray (j)	$y_{C5,j-1}$	$y_{C6,j-1}$	$y_{C7,j-1}$	$y_{C8,j-1}$	$y_{C9,j-1}$	$y_{C10,j-1}$	$y_{C11,j-1}$
15	0.0201	0.2908	0.5665	0.1178	0.0020	0.0004	0.0004
14	0.0061	0.1474	0.5644	0.2599	0.0107	0.0056	0.0056
13	0.0037	0.0797	0.4062	0.3713	0.0368	0.0510	0.0510
12	0.0032	0.0536	0.1972	0.2576	0.0599	0.2141	0.2141
11	0.0031	0.0469	0.1086	0.0856	0.0397	0.3579	0.3579
10	0.0031	0.0459	0.0948	0.0334	0.0182	0.4021	0.4021
9	0.0031	0.0458	0.0934	0.0236	0.0080	0.4129	0.4129
8	0.0031	0.0458	0.0934	0.0219	0.0037	0.4159	0.4159
7	0.0031	0.0459	0.0936	0.0217	0.0019	0.4168	0.4168
6	0.0031	0.0460	0.0939	0.0217	0.0011	0.4169	0.4169
5	0.0284	0.3526	0.5232	0.0830	0.0084	0.0033	0.0013
4	0.0056	0.1471	0.4871	0.1863	0.0805	0.0678	0.0256
3	0.0006	0.0265	0.1874	0.1681	0.1925	0.3084	0.1163
2	0.0002	0.0039	0.0361	0.0773	0.1818	0.5089	0.1918
1	0.0002	0.0023	0.0129	0.0446	0.1361	0.5840	0.2199

Multicomponent Distillation Calculation for Liquid Phase

Tray (j)	$x_{C5,j}$	$x_{C6,j}$	$x_{C7,j}$	$x_{C8,j}$	$x_{C9,j}$	$x_{C10,j}$	$x_{C11,j}$
15	0.0201	0.2908	0.5665	0.1178	0.0020	0.0004	0.0004
14	0.0036	0.1216	0.5640	0.2855	0	0.0066	0
13	0.0007	0.0417	0.3774	0.4169	0.0430	0.0601	0.0601
12	0.0002	0.0109	0.1309	0.2827	0.0703	0.2525	0.2525
11	0.0001	0.0031	0.0263	0.0798	0.0465	0.4221	0.4221
10	0.0001	0.0019	0.0101	0.0182	0.0212	0.4743	0.4743
9	0.0001	0.0018	0.0083	0.0066	0.0091	0.4871	0.4871
8	0.0001	0.0018	0.0084	0.0047	0.0040	0.4906	0.4906
7	0.0001	0.0019	0.0086	0.0044	0.0019	0.4916	0.4916
6	0.0001	0.0019	0.0090	0.0045	0.0010	0.4918	0.4918
5	0.0060	0.1642	0.5447	0.1827	0.0463	0.0405	0.0156
4	0.0061	0.1660	0.5471	0.1806	0.0458	0.0393	0.0151
3	0.0005	0.0279	0.2041	0.1598	0.1741	0.3147	0.1189
2	0.0000	0.0020	0.0309	0.0559	0.1618	0.5442	0.2053
1	0.0000	0.0002	0.0043	0.0184	0.1096	0.6301	0.2374

Operating condition :			
	Pressure	14.7	psia
	Feed inlet temperature	150	^{o}C
	Product output temperature	95.5	^{o}C
	Bottom output temperature	137.2	^{o}C
	Feed flowrate	45	GPM
	Distillate (Rubber Solvent)	3.9	GPM
	Reflux feed rate	21.7	GPM

Multicomponent Distillation Calculation for Vapor Phase

Tray (j)	$y_{C5,j-1}$	$y_{C6,j-1}$	$y_{C7,j-1}$	$y_{C8,j-1}$	$y_{C9,j-1}$	$y_{C10,j-1}$	$y_{C11,j-1}$
15	0.0248	0.3983	0.5070	0.0673	0.0005	0.0015	0.0000
14	0.0085	0.2323	0.5772	0.1588	0.0028	0.0202	0.0000
13	0.0049	0.1270	0.4511	0.2365	0.0102	0.1703	0.0000
12	0.0040	0.0756	0.1970	0.1458	0.0147	0.5627	0.0000
11	0.0039	0.0646	0.1000	0.0459	0.0091	0.7764	0.0000
10	0.0039	0.0634	0.0865	0.0191	0.0045	0.8226	0.0000
9	0.0039	0.0633	0.0852	0.0138	0.0022	0.8315	0.0000
8	0.0039	0.0634	0.0853	0.0129	0.0011	0.8333	0.0000
7	0.0039	0.0636	0.0857	0.0127	0.0006	0.8334	0.0000
6	0.0039	0.0637	0.0860	0.0128	0.0004	0.8331	0.0000
5	0.0306	0.4379	0.4555	0.0607	0.0103	0.0038	0.0012
4	0.0070	0.2069	0.4639	0.1493	0.0932	0.0596	0.0200
3	0.0009	0.0455	0.2160	0.1579	0.2395	0.2543	0.0859
2	0.0002	0.0062	0.0517	0.0923	0.2622	0.4387	0.1487
1	0.0002	0.0024	0.0167	0.0603	0.2161	0.5258	0.1785

Multicomponent Distillation Calculation for Liquid Phase

Tray (j)	$x_{C5,j}$	$x_{C6,j}$	$x_{C7,j}$	$x_{C8,j}$	$x_{C9,j}$	$x_{C10,j}$	$x_{C11,j}$
15	0.0248	0.3983	0.5070	0.0673	0.0005	0.0015	0.0000
14	0.0056	0.2025	0.5898	0.1753	0	0.0236	0
13	0.0013	0.0782	0.4411	0.2669	0.0120	0.2006	0.0000
12	0.0003	0.0176	0.1413	0.1599	0.0173	0.6636	0.0000
11	0.0001	0.0046	0.0269	0.0421	0.0107	0.9156	0.0000
10	0.0001	0.0032	0.0109	0.0104	0.0052	0.9702	0.0000
9	0.0001	0.0031	0.0094	0.0042	0.0025	0.9807	0.0000
8	0.0001	0.0032	0.0095	0.0031	0.0013	0.9828	0.0000
7	0.0001	0.0034	0.0099	0.0029	0.0007	0.9830	0.0000
6	0.0001	0.0036	0.0104	0.0030	0.0004	0.9826	0.0000
5	0.0077	0.2325	0.5189	0.1305	0.0567	0.0405	0.0131
4	0.0079	0.2349	0.5210	0.1285	0.0561	0.0391	0.0126
3	0.0008	0.0499	0.2369	0.1383	0.2237	0.2622	0.0881
2	0.0000	0.0049	0.0486	0.0632	0.2498	0.4735	0.1600
1	0.0000	0.0005	0.0085	0.0264	0.1970	0.5733	0.1943

Operating condition :	Pressure	14.7	psia
	Feed inlet temperature	140	^{O}C
	Product output temperature	89	^{O}C
	Bottom output temperature	128	^{O}C
	Feed flowrate	41	GPM
	Distillate (Rubber Solvent)	3.9	GPM
	Reflux feed rate	21.7	GPM

Multicomponent Distillation Calculation for Vapor Phase

Tray (j)	$y_{C5,j-1}$	$y_{C6,j-1}$	$y_{C7,j-1}$	$y_{C8,j-1}$	$y_{C9,j-1}$	$y_{C10,j-1}$	$y_{C11,j-1}$
15	0.0175	0.3290	0.5977	0.0534	0.0000	0.0000	0.0000
14	0.0059	0.1880	0.6756	0.1302	0.0000	0.0000	0.0000
13	0.0036	0.1152	0.6327	0.2481	0.0000	0.0000	0.0000
12	0.0031	0.0843	0.5220	0.3902	0.0000	0.0000	0.0000
11	0.0030	0.0721	0.4012	0.5233	0.0000	0.0000	0.0000
10	0.0030	0.0672	0.3067	0.6227	0.0000	0.0000	0.0000
9	0.0030	0.0653	0.2463	0.6851	0.0000	0.0000	0.0000
8	0.0030	0.0645	0.2123	0.7198	0.0000	0.0000	0.0000
7	0.0030	0.0643	0.1948	0.7375	0.0000	0.0000	0.0000
6	0.0030	0.0645	0.1867	0.7455	0.0000	0.0000	0.0000
5	0.0229	0.3775	0.5409	0.0417	0.0089	0.0063	0.0018
4	0.0047	0.1627	0.5093	0.0946	0.0831	0.1131	0.0326
3	0.0004	0.0261	0.1749	0.0789	0.1777	0.4208	0.1212
2	0.0001	0.0028	0.0298	0.0389	0.1601	0.5966	0.1718
1	0.0001	0.0013	0.0091	0.0263	0.1264	0.6497	0.1871

Multicomponent Distillation Calculation for Liquid Phase

Tray (j)	$x_{C5,j}$	$x_{C6,j}$	$x_{C7,j}$	$x_{C8,j}$	$x_{C9,j}$	$x_{C10,j}$	$x_{C11,j}$
15	0.0175	0.3290	0.5977	0.0534	0.0000	0.0000	0.0000
14	0.0038	0.1627	0.6896	0.1440	0	0.0000	0
13	0.0011	0.0768	0.6390	0.2831	0.0000	0.0000	0.0000
12	0.0006	0.0403	0.5085	0.4507	0.0000	0.0000	0.0000
11	0.0004	0.0259	0.3659	0.6078	0.0000	0.0000	0.0000
10	0.0004	0.0202	0.2544	0.7250	0.0000	0.0000	0.0000
9	0.0004	0.0179	0.1832	0.7986	0.0000	0.0000	0.0000
8	0.0004	0.0170	0.1431	0.8396	0.0000	0.0000	0.0000
7	0.0004	0.0168	0.1224	0.8604	0.0000	0.0000	0.0000
6	0.0004	0.0169	0.1129	0.8699	0.0000	0.0000	0.0000
5	0.0052	0.1851	0.5807	0.0895	0.0482	0.0708	0.0204
4	0.0053	0.1872	0.5833	0.0883	0.0477	0.0684	0.0197
3	0.0004	0.0289	0.1959	0.0702	0.1573	0.4249	0.1224
2	0.0000	0.0019	0.0278	0.0237	0.1369	0.6286	0.1810
1	0.0000	0.0002	0.0038	0.0092	0.0979	0.6901	0.1988

Operating condition :	Pressure	14.7	psia
	Feed inlet temperature	140	°C
	Product output temperature	89	°C
	Bottom output temperature	128	°C
	Feed flowrate	47	GPM
	Distillate (Rubber Solvent)	3.9	GPM
	Reflux feed rate	21.7	GPM

Multicomponent Distillation Calculation for Vapor Phase

Tray (j)	$y_{C5,j-1}$	$y_{C6,j-1}$	$y_{C7,j-1}$	$y_{C8,j-1}$	$y_{C9,j-1}$	$y_{C10,j-1}$	$y_{C11,j-1}$
15	0.0175	0.3290	0.5977	0.0534	0.0000	0.0000	0.0000
14	0.0059	0.1880	0.6756	0.1302	0.0000	0.0000	0.0000
13	0.0036	0.1152	0.6327	0.2481	0.0000	0.0000	0.0000
12	0.0031	0.0843	0.5220	0.3902	0.0000	0.0000	0.0000
11	0.0030	0.0721	0.4012	0.5233	0.0000	0.0000	0.0000
10	0.0030	0.0672	0.3067	0.6227	0.0000	0.0000	0.0000
9	0.0030	0.0653	0.2463	0.6851	0.0000	0.0000	0.0000
8	0.0030	0.0645	0.2123	0.7198	0.0000	0.0000	0.0000
7	0.0030	0.0643	0.1948	0.7375	0.0000	0.0000	0.0000
6	0.0030	0.0645	0.1867	0.7455	0.0000	0.0000	0.0000
5	0.0229	0.3777	0.5411	0.0410	0.0088	0.0065	0.0020
4	0.0046	0.1620	0.5071	0.0913	0.0824	0.1174	0.0353
3	0.0004	0.0252	0.1698	0.0737	0.1733	0.4286	0.1290
2	0.0000	0.0024	0.0279	0.0353	0.1548	0.5991	0.1804
1	0.0000	0.0010	0.0081	0.0237	0.1226	0.6492	0.1955

Multicomponent Distillation Calculation for Liquid Phase

Tray (j)	$x_{C5,j}$	$x_{C6,j}$	$x_{C7,j}$	$x_{C8,j}$	$x_{C9,j}$	$x_{C10,j}$	$x_{C11,j}$
15	0.0175	0.3290	0.5977	0.0534	0.0000	0.0000	0.0000
14	0.0038	0.1627	0.6896	0.1440	0	0.0000	0
13	0.0011	0.0768	0.6390	0.2831	0.0000	0.0000	0.0000
12	0.0006	0.0403	0.5085	0.4507	0.0000	0.0000	0.0000
11	0.0004	0.0259	0.3659	0.6078	0.0000	0.0000	0.0000
10	0.0004	0.0202	0.2544	0.7250	0.0000	0.0000	0.0000
9	0.0004	0.0179	0.1832	0.7986	0.0000	0.0000	0.0000
8	0.0004	0.0170	0.1431	0.8396	0.0000	0.0000	0.0000
7	0.0004	0.0168	0.1224	0.8604	0.0000	0.0000	0.0000
6	0.0004	0.0169	0.1129	0.8699	0.0000	0.0000	0.0000
5	0.0052	0.1847	0.5791	0.0878	0.0478	0.0734	0.0221
4	0.0053	0.1867	0.5818	0.0866	0.0473	0.0709	0.0214
3	0.0004	0.0282	0.1909	0.0663	0.1526	0.4316	0.1300
2	0.0000	0.0018	0.0265	0.0218	0.1312	0.6292	0.1894
1	0.0000	0.0001	0.0035	0.0083	0.0938	0.6873	0.2069

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