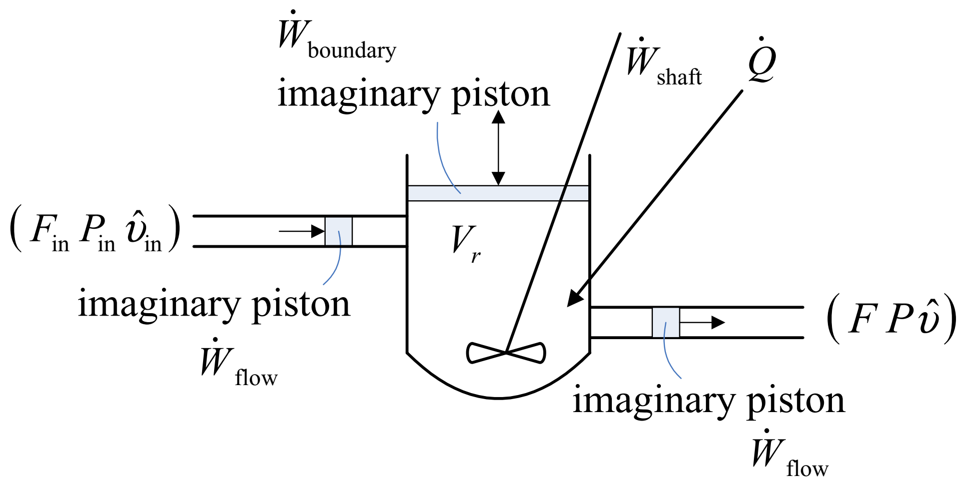

$\dot{W}_{\text{boundary}}$
imaginary piston
$\dot{W}_{\text{shaft}}$
$\dot{Q}$
$(F_{\text{in}}\ P_{\text{in}}\ \hat{v}_{\text{in}})$
V_r
imaginary piston
$\dot{W}_{\text{flow}}$
$(F\ P\ \hat{v})$
imaginary piston
$\dot{W}_{\text{flow}}$

FIGURE 5.1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
30		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	N(N2)	Feed
31		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	N(H2)	Feed
32		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	382.83	N(N2)	Reactor In
33		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1148.5	N(H2)	Reactor In
34		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8666	N(NH3)	Reactor In
35		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	287.12	N(N2)	Reactor Out
36		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	861.37	N(H2)	Reactor Out
37		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	195.28	N(NH3)	Reactor Out
38		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1.4356	N(N2)	Product
39		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4.3068	N(H2)	Product
40		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	191.38	N(NH3)	Product
41		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	285.69	N(N2)	Vapor Out
42		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	857.06	N(H2)	Vapor Out
43		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3.9056	N(NH3)	Vapor Out
44		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2.8569	N(N2)	Purge
45		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8.5706	N(H2)	Purge
46		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.0391	N(NH3)	Purge
47		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	282.83	N(N2)	Recycle
48		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	848.49	N(H2)	Recycle
49		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3.8666	N(NH3)	Recycle

FIGURE 5.11

	A	B	C	D	E	F	G	H	I	J	K	L	M
5		x(0)	x(1)	x(2)	x(3)	x(4)	x(5)	x(6)	x(7)	x(8)			
6		Reactor Out				Product			Vapor Out				
7		N(N2)	N(H2)	N(NH3)	N(N2)	N(H2)	N(NH3)	N(N2)	N(H2)	N(NH3)	RHS		
8	Feed	1									287.12		
9			1								861.37		
10	Specs			1							195.28		
11	Separator 1	-1			1			1			0		
12			-1			1			1		0		
13	Flash			-1			1			1	0		
14	Separator	0.005			-1						0		
15			0.005			-1					0		
16				0.98			-1				0		
17													
18													
19													
20													
21		1	0	0	0	0	0	0	0	0	287.12	N(N2)	Reactor Out
22		0	1	0	0	0	0	0	0	0	861.37	N(H2)	Reactor Out
23		0	0	1	0	0	0	0	0	0	195.28	N(NH3)	Reactor Out
24		0	0	0	1	0	0	0	0	0	0.67104	N(N2)	Product
25		0	0	0	0	1	0	0	0	0	2.68222	N(H2)	Product
26		0	0	0	0	0	1	0	0	0	178.168	N(NH3)	Product
27		0	0	0	0	0	0	1	0	0	286.449	N(N2)	Vapor Out
28		0	0	0	0	0	0	0	1	0	858.688	N(H2)	Vapor Out
29		0	0	0	0	0	0	0	0	1	17.1117	N(NH3)	Vapor Out
30													
31													
32													
33													
34		1									287.12		
35			1								861.37		
36				1							195.28		
37		-1			1			1			0		
38			-1			1			1		0		
39				-1			1			1	0		
40		-8E-04	-0.0008	0.005	-0.005	-0.005	-0.0048	0	0.0008	0.0008	3.6E-07		
41		0	0	0	-0.366	0.001	0.0014	0	-2E-04	-2E-04	1.1E-10		
42		0	0	0	0.004	-0.271	0.0041	-0	0.0002	-6E-04	-5E-10		

FIGURE 5.13

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	***Ammonia Material Balance using Gauss Jordan Elimination and Newton Raphson***																					
2																						
3	Reaction $N_2 + 3H_2 \rightarrow NH_3$					0.25	conversion															
4																						
5		x(0)	x(1)	x(2)	x(3)	x(4)	x(5)	x(6)	x(7)	x(8)	x(9)	x(10)	x(11)	x(12)	x(13)	x(14)	x(15)	x(16)	x(17)	x(18)	x(19)	
6		Feed		Reactor In			Reactor Out				Product			Vapor Out			Purge			Recycle		
7		$N(N_2)$	$N(H_2)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	$N(N_2)$	$N(H_2)$	$N(NH_3)$	RHS
8	Feed	1																				100
9	Specs		1																			300
10	Mixer	1		-1															1			0
11	Material		1		-1															1		0
12	Balances					-1															1	0
13	Reactor			0.75			-1															0
14	Balances			-0.75	1			-1														0
15				0.5		1			-1													0
16	Separator 2												0.01			-1						0
17														0.01			-1					0
18															0.01			-1				0
19													1			-1			-1			0
20														1			-1			-1		0
21															1			-1			-1	0
22	Separator 1						1			-1			-1									0
23								1			-1			-1								0
24	Flash								1			-1			-1							0
25	Separator						0.005			-1												0
26								0.005			-1											0
27									0.98			-1										0

(a)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
32		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	$N(N_2)$	Feed
33		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	$N(H_2)$	Feed
34		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385.42	$N(N_2)$	Reactor In
35		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1100.5	$N(H_2)$	Reactor In
36		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.227	$N(NH_3)$	Reactor In
37		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	289.07	$N(N_2)$	Reactor Out
38		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	811.41	$N(H_2)$	Reactor Out
39		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	208.94	$N(NH_3)$	Reactor Out
40		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.762	$N(N_2)$	Product
41		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2.8494	$N(H_2)$	Product
42		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	192.55	$N(NH_3)$	Product
43		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	288.3	$N(N_2)$	Vapor Out
44		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	808.56	$N(H_2)$	Vapor Out
45		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	16.391	$N(NH_3)$	Vapor Out
46		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2.883	$N(N_2)$	Purge
47		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8.0856	$N(H_2)$	Purge
48		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.1639	$N(NH_3)$	Purge
49		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	285.42	$N(N_2)$	Recycle
50		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	800.47	$N(H_2)$	Recycle
51		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	16.227	$N(NH_3)$	Recycle

(b)

FIGURE 5.14ab

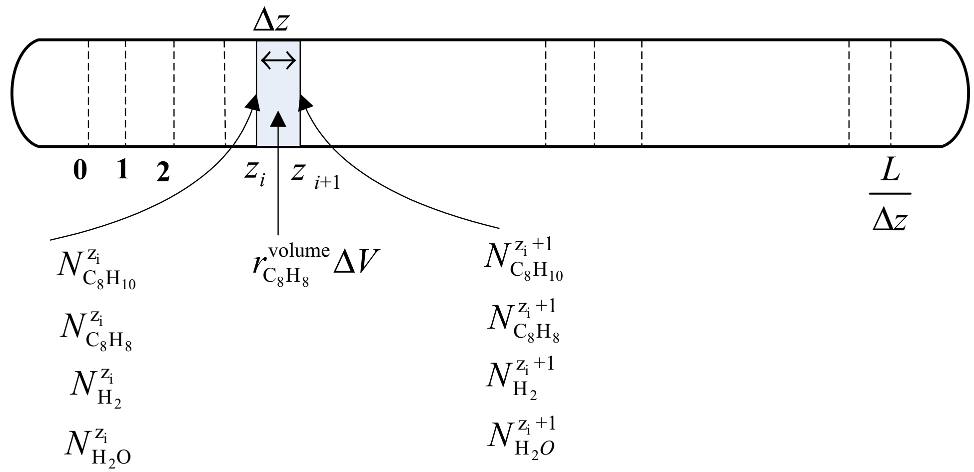

Δz
0
1
2
z_i
z_{i+1}
$\frac{L}{\Delta z}$
$N^{z_i}_{C_8H_{10}}$
$N^{z_i}_{C_8H_8}$
$N^{z_i}_{H_2}$
$N^{z_i}_{H_2O}$
$r^{volume}_{C_8H_8}\Delta V$
$N^{z_i+1}_{C_8H_{10}}$
$N^{z_i+1}_{C_8H_8}$
$N^{z_i+1}_{H_2}$
$N^{z_i+1}_{H_2O}$

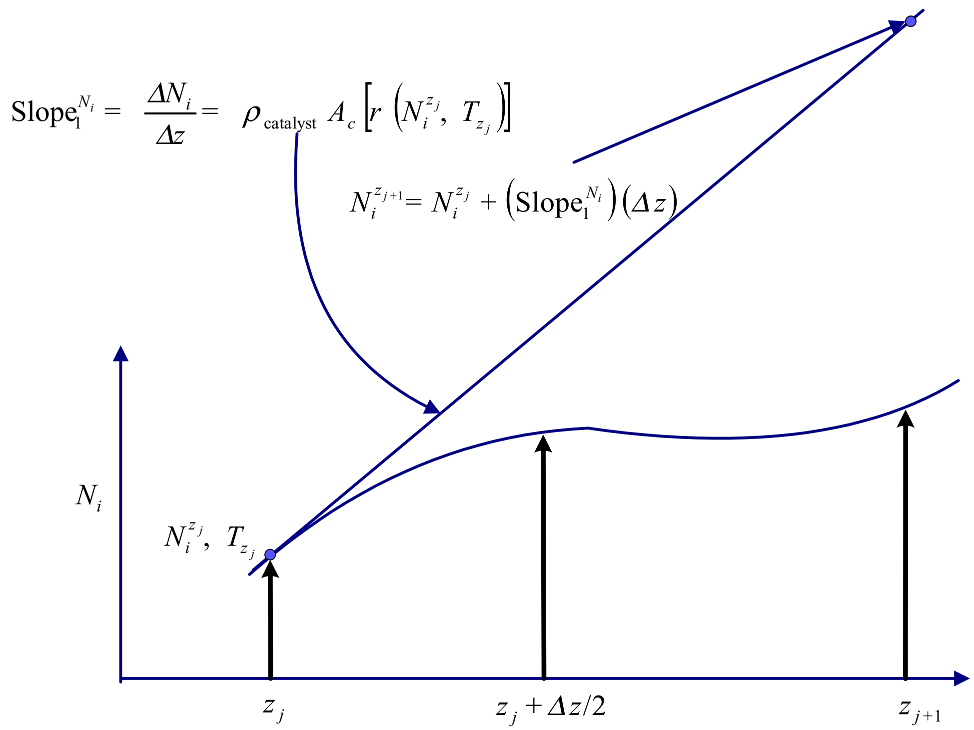
FIGURE 5.17

```
Option Explicit
Public Sub Ethylbenzene_Kinetics()

    Dim N_EB(), P_EB(), Conversion_EB() As Double
    Dim N_S(), P_S(), delta_N_S() As Double
    Dim N_H2(), P_H2() As Double
    Dim N_H2O(), P_H2O() As Double

    Dim Temp(), N_Total(), Keq(), r_S(), Q() As Double

    Dim delta_z, Pi, radius, CSA As Double
    Dim rho_catalyst, delta_H_reaction, P_Total As Double
    Dim Cp, MW_EB, MW_S, MW_H2, MW_H2O, F_Total, FCp As Double

    Dim Number_zSteps, i As Integer

    'Set known reactor conditions and constants
    radius = 2.3 '  PFR tube radius
    Pi = 3.14159
    CSA = Pi * (radius) ^ 2 ' cross-sectional area ft^2

    rho_catalyst = 90   ' lbs/ft^3

    P_Total = 1.2   ' Reactor Pressure assumed constant
    delta_H_reaction = 60000.0#  ' Heat of Reaction (Btu/lb-mole)
    Cp = 0.52 ' Btu/(lb-R)

    MW_EB = 106.17
    MW_S = 104.15
    MW_H2 = 2.016
    MW_H2O = 18.015

    ' Here we set the step size down the reactor and the number of steps (=length)
    delta_z = 0.1       ' step size z direction [=] ft
    Number_zSteps = 90

    ReDim N_EB(Number_zSteps + 2), P_EB(Number_zSteps + 2), Conversion_EB(Number_zSteps
+ 2)
    ReDim N_S(Number_zSteps + 2), P_S(Number_zSteps + 2), delta_N_S(Number_zSteps + 2)
    ReDim N_H2(Number_zSteps + 2), P_H2(Number_zSteps + 2)
    ReDim N_H2O(Number_zSteps + 2), P_H2O(Number_zSteps + 2)

    ReDim Temp(Number_zSteps + 2), N_Total(Number_zSteps + 2), Keq(Number_zSteps + 2), _
                    r_S(Number_zSteps + 2), Q(Number_zSteps + 2)


    ' Establish PFR tube radius initial conditions: moles/s, temperature into PFR, z = 0
    Temp(0) = 1616  ' Temperature z = 0
    N_EB(0) = 18.4615 / 3600 ' Moles Ethylbenzene/hr, z = 0
    N_S(0) = 0.1212 / 3600
    N_H2(0) = 0.0 / 3600
    N_H2O(0) = 353.0745 / 3600
    N_Total(0) = N_EB(0) + N_S(0) + N_H2(0) + N_H2O(0)

    'Calculate the flow rate heat capacity, FCp, of the reacting fluid - assumed
constant
    F_Total = (N_EB(0) * MW_EB + N_S(0) * MW_S _
             + N_H2(0) * MW_H2 + N_H2O(0) * MW_H2O) ' Total Flow lbs/s
    FCp = F_Total * Cp ' Btu/lb-s

    ' We next set up the numerical integration to find the moles EB reacted
    ' here using a first-order Eulerian difference

    For i = 0 To Number_zSteps

        ' Monitor key values on the Excel sheet

        Sheet1.Cells(6 + i, 4) = delta_z * (i)
        Conversion_EB(i) = ((N_EB(0) - N_EB(i)) / N_EB(0)) * 100
        Sheet1.Cells(6 + i, 5) = Conversion_EB(i)
        Sheet1.Cells(6 + i, 6) = Temp(i)  ' R
        Sheet1.Cells(6 + i, 7) = Temp(i) / 1.8 - 273.15 ' C
        Sheet1.Cells(6 + i, 8) = Temp(i) - 459.67  ' F
        Sheet1.Cells(6 + i, 9) = N_EB(i)
        Sheet1.Cells(6 + i, 10) = N_S(i)
        Sheet1.Cells(6 + i, 11) = N_H2(i)
        Sheet1.Cells(6 + i, 12) = N_H2O(i)

        'Calculate species partial pressures

        P_EB(i) = (N_EB(i) / N_Total(i)) * P_Total
        P_S(i) = (N_S(i) / N_Total(i)) * P_Total
        P_H2(i) = (N_H2(i) / N_Total(i)) * P_Total
        P_H2O(i) = (N_H2O(i) / N_Total(i)) * P_Total
```

FIGURE 5.20a

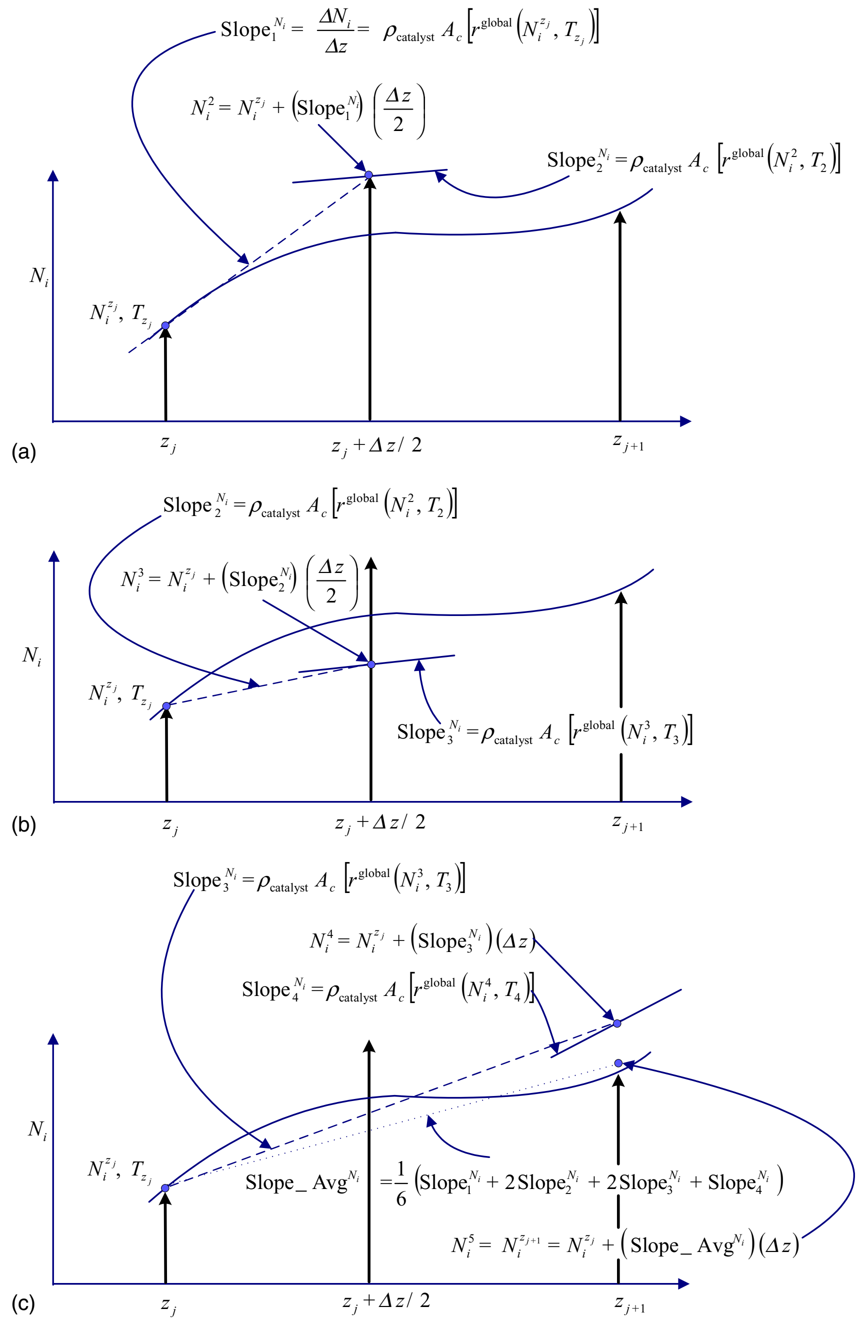
```
        ' Calculate Keq

        Keq(i) = Exp(15.596 - 26734.68 / Temp(i))

        '  Calcualte the reaction rate lb-moles Styrene/(ft^3-sec)

        r_S(i) = rho_catalyst * 3.5 * Exp(-19800 / Temp(i)) * (P_EB(i) - (P_S(i) *
P_H2(i) / Keq(i)))

        delta_N_S(i) = r_S(i) * CSA * delta_z

        Q(i) = delta_N_S(i) * (-delta_H_reaction)

        ' Calculate conditions at z + delta_z
        Temp(i + 1) = Temp(i) + Q(i) / (FCp)
        N_EB(i + 1) = N_EB(i) - delta_N_S(i)
        N_S(i + 1) = N_S(i) + delta_N_S(i)
        N_H2(i + 1) = N_H2(i) + delta_N_S(i)
        N_H2O(i + 1) = N_H2O(i)
        N_Total(i + 1) = N_EB(i + 1) + N_S(i + 1) + N_H2(i + 1) + N_H2O(i + 1)
    Next i

End Sub
```

FIGURE 5.20b



$\text{Slope}_1^{N_i} = \dfrac{\Delta N_i}{\Delta z} = \rho_{\text{catalyst}} A_c \left[r\left(N_i^{z_j}, T_{z_j} \right) \right]$
$N_i^{z_{j+1}} = N_i^{z_j} + \left(\text{Slope}_1^{N_i} \right) (\Delta z)$
N_i
$N_i^{z_j}, T_{z_j}$
z_j
$z_j + \Delta z/2$
z_{j+1}

FIGURE 5.22



$\text{Slope}_1^{N_i} = \frac{\Delta N_i}{\Delta z} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^{z_j}, T_{z_j}\right)\right]$
$N_i^2 = N_i^{z_j} + \left(\text{Slope}_1^{N_i}\right)\left(\frac{\Delta z}{2}\right)$
$\text{Slope}_2^{N_i} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^2, T_2\right)\right]$
N_i
$N_i^{z_j},\ T_{z_j}$
z_j
$z_j + \Delta z/2$
z_{j+1}
(a)
$\text{Slope}_2^{N_i} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^2, T_2\right)\right]$
$N_i^3 = N_i^{z_j} + \left(\text{Slope}_2^{N_i}\right)\left(\frac{\Delta z}{2}\right)$
N_i
$N_i^{z_j},\ T_{z_j}$
$\text{Slope}_3^{N_i} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^3, T_3\right)\right]$
z_j
$z_j + \Delta z/2$
z_{j+1}
(b)
$\text{Slope}_3^{N_i} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^3, T_3\right)\right]$
$N_i^4 = N_i^{z_j} + \left(\text{Slope}_3^{N_i}\right)(\Delta z)$
$\text{Slope}_4^{N_i} = \rho_{\text{catalyst}} A_c \left[r^{\text{global}}\left(N_i^4, T_4\right)\right]$
N_i
$N_i^{z_j},\ T_{z_j}$
$\text{Slope\_Avg}^{N_i} = \frac{1}{6}\left(\text{Slope}_1^{N_i} + 2\,\text{Slope}_2^{N_i} + 2\,\text{Slope}_3^{N_i} + \text{Slope}_4^{N_i}\right)$
$N_i^5 = N_i^{z_{j+1}} = N_i^{z_j} + \left(\text{Slope\_Avg}^{N_i}\right)(\Delta z)$
z_j
$z_j + \Delta z/2$
z_{j+1}
(c)

FIGURE 5.23

	A	B	C	D	E	F	G	H	I	J	K	L
5				distance z (ft)	% conversion EB	Temperature (R)	Temperature (C)	Temperature (F)	EB mol/s	S mol/s	H2 mol/s	H20 mol/s
6				0	0.00	1616.00	624.63	1156.33	5.13E-03	3.37E-05	0.00E+00	9.81E-02
7				0.1	2.78	1608.88	620.67	1149.21	4.99E-03	1.76E-04	1.43E-04	9.81E-02
8				0.2	5.35	1602.32	617.03	1142.65	4.85E-03	3.08E-04	2.74E-04	9.81E-02
9				0.3	7.73	1596.24	613.65	1136.57	4.73E-03	4.30E-04	3.96E-04	9.81E-02
10				0.4	9.94	1590.59	610.51	1130.92	4.62E-03	5.43E-04	5.10E-04	9.81E-02
11				0.5	12.01	1585.31	607.58	1125.64	4.51E-03	6.49E-04	6.16E-04	9.81E-02
12				0.6	13.94	1580.37	604.83	1120.70	4.41E-03	7.49E-04	7.15E-04	9.81E-02
13				0.7	15.76	1575.72	602.25	1116.05	4.32E-03	8.42E-04	8.08E-04	9.81E-02
14				0.8	17.47	1571.35	599.82	1111.68	4.23E-03	9.29E-04	8.96E-04	9.81E-02
15				0.9	19.08	1567.22	597.53	1107.55	4.15E-03	1.01E-03	9.79E-04	9.81E-02
16				1	20.61	1563.31	595.36	1103.64	4.07E-03	1.09E-03	1.06E-03	9.81E-02
17				1.1	22.06	1559.60	593.30	1099.93	4.00E-03	1.17E-03	1.13E-03	9.81E-02
18				1.2	23.44	1556.09	591.34	1096.42	3.93E-03	1.24E-03	1.20E-03	9.81E-02
19				1.3	24.75	1552.74	589.48	1093.07	3.86E-03	1.30E-03	1.27E-03	9.81E-02
20				1.4	26.00	1549.55	587.71	1089.88	3.80E-03	1.37E-03	1.33E-03	9.81E-02
21				1.5	27.19	1546.50	586.02	1086.83	3.73E-03	1.43E-03	1.39E-03	9.81E-02
22				1.6	28.32	1543.60	584.40	1083.93	3.68E-03	1.49E-03	1.45E-03	9.81E-02
23				1.7	29.41	1540.82	582.86	1081.15	3.62E-03	1.54E-03	1.51E-03	9.81E-02
24				1.8	30.45	1538.15	581.38	1078.48	3.57E-03	1.60E-03	1.56E-03	9.81E-02
25				1.9	31.45	1535.60	579.96	1075.93	3.52E-03	1.65E-03	1.61E-03	9.81E-02
26				2	32.41	1533.16	578.60	1073.49	3.47E-03	1.70E-03	1.66E-03	9.81E-02
27				2.1	33.33	1530.81	577.30	1071.14	3.42E-03	1.74E-03	1.71E-03	9.81E-02
28				2.2	34.21	1528.55	576.04	1068.88	3.37E-03	1.79E-03	1.75E-03	9.81E-02
29				2.3	35.06	1526.37	574.84	1066.70	3.33E-03	1.83E-03	1.80E-03	9.81E-02

FIGURE 5.24

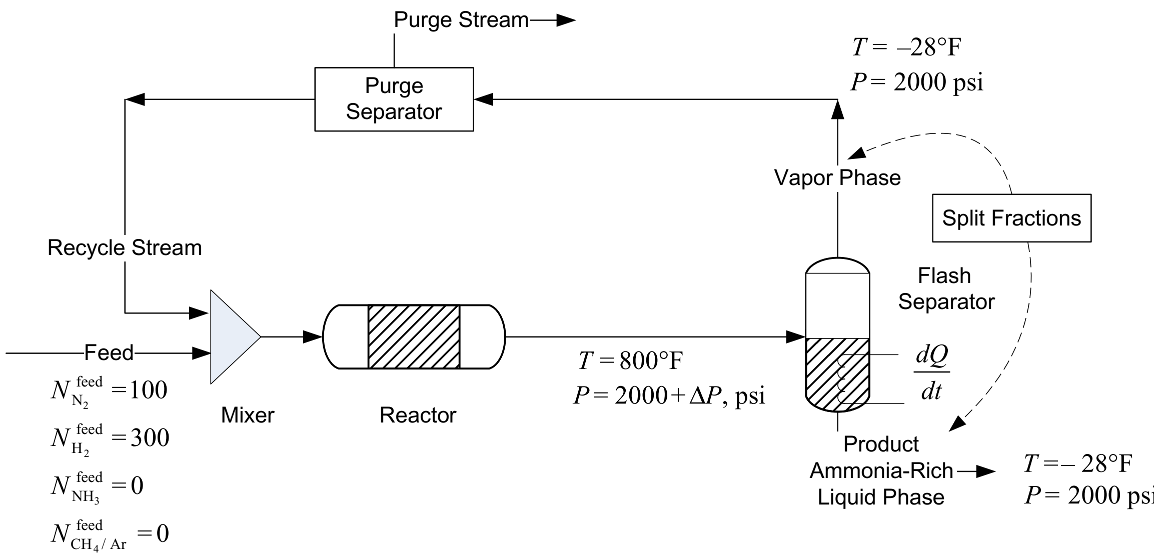

Purge Stream
Purge Separator
$T = -28°F$
$P = 2000$ psi
Vapor Phase
Split Fractions
Recycle Stream
Flash Separator
Feed
$N_{N_2}^{feed} = 100$
$N_{H_2}^{feed} = 300$
$N_{NH_3}^{feed} = 0$
$N_{CH_4/Ar}^{feed} = 0$
Mixer
Reactor
$T = 800°F$
$P = 2000 + \Delta P$, psi
$\frac{dQ}{dt}$
Product Ammonia-Rich Liquid Phase
$T = -28°F$
$P = 2000$ psi

FIGURE 5.4

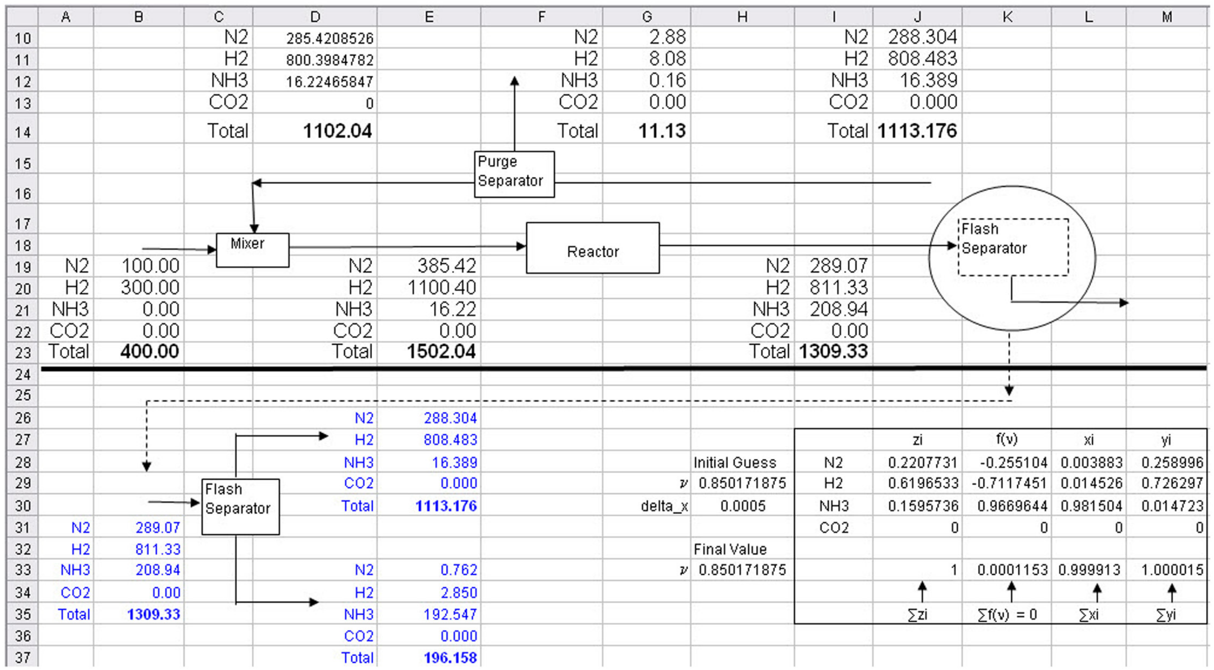
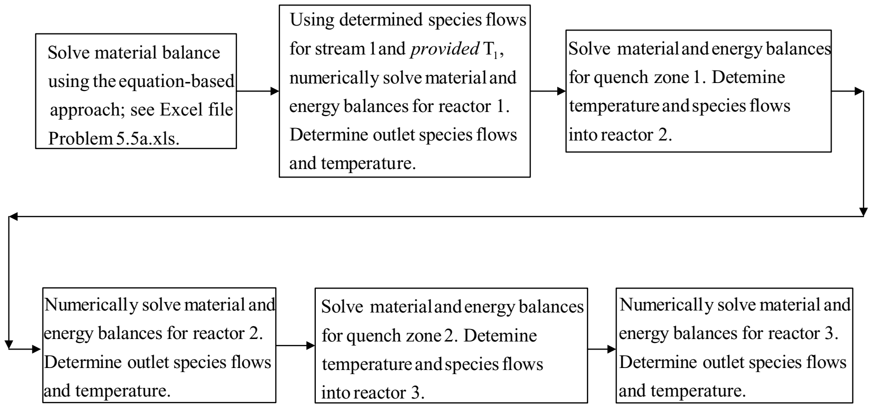

N2 285.4208526
H2 800.3984782
NH3 16.22465847
CO2 0
Total 1102.04
N2 2.88
H2 8.08
NH3 0.16
CO2 0.00
Total 11.13
N2 288.304
H2 808.483
NH3 16.389
CO2 0.000
Total 1113.176
Purge Separator
Mixer
Reactor
Flash Separator
N2 100.00
H2 300.00
NH3 0.00
CO2 0.00
Total 400.00
N2 385.42
H2 1100.40
NH3 16.22
CO2 0.00
Total 1502.04
N2 289.07
H2 811.33
NH3 208.94
CO2 0.00
Total 1309.33
N2 288.304
H2 808.483
NH3 16.389
CO2 0.000
Total 1113.176
Flash Separator
N2 289.07
H2 811.33
NH3 208.94
CO2 0.00
Total 1309.33
N2 0.762
H2 2.850
NH3 192.547
CO2 0.000
Total 196.158
Initial Guess
ν 0.850171875
delta_x 0.0005
Final Value
ν 0.850171875
zi f(v) xi yi
N2 0.2207731 -0.255104 0.003883 0.258996
H2 0.6196533 -0.7117451 0.014526 0.726297
NH3 0.1595736 0.9669644 0.981504 0.014723
CO2 0 0 0 0
1 0.0001153 0.999913 1.000015
∑zi ∑f(v) = 0 ∑xi ∑yi

FIGURE 5.9

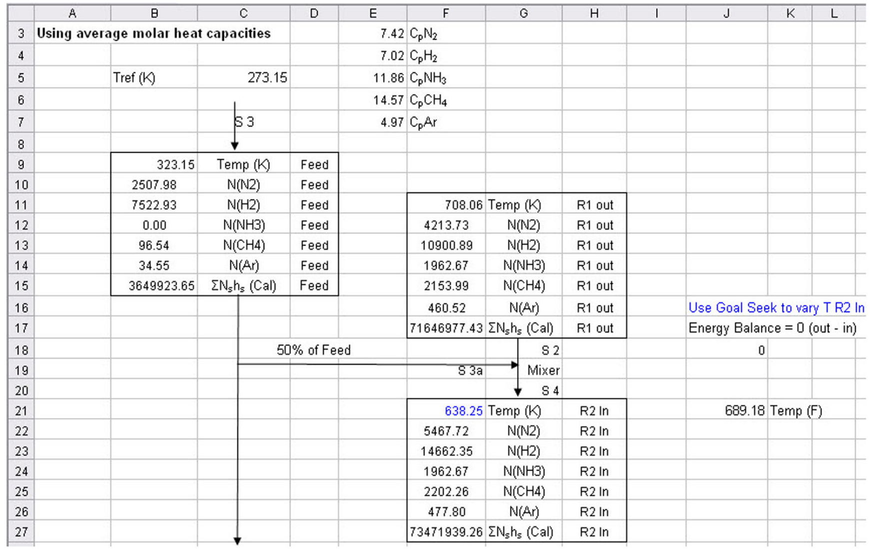


(b)

D	E	F	G	H	I	J	K	L	M	N
		P_Total	225							
distance z (ft)	% conversion N2	Temperature (K)	Temperature (C)	Temperature (F)	N2	H2	NH3	y-NH3	CH4	Ar
0	0.00	602.59	329.44	624.99	4957.32	13131.68	475.47	0.02	2153.99	460.52
0.1	0.23	604.22	331.07	627.92	4945.72	13096.88	498.67	0.02	2153.99	460.52
0.2	0.46	605.82	332.67	630.80	4934.33	13062.72	521.45	0.02	2153.99	460.52
0.3	0.69	607.39	334.24	633.64	4923.13	13029.11	543.85	0.03	2153.99	460.52
0.4	0.91	608.94	335.79	636.43	4912.09	12995.99	565.93	0.03	2153.99	460.52
0.5	1.13	610.48	337.33	639.19	4901.19	12963.29	587.73	0.03	2153.99	460.52
0.6	1.35	611.99	338.84	641.92	4890.41	12930.96	609.28	0.03	2153.99	460.52
0.7	1.56	613.49	340.34	644.62	4879.75	12898.96	630.62	0.03	2153.99	460.52
0.8	1.78	614.98	341.83	647.30	4869.17	12867.24	651.76	0.03	2153.99	460.52
0.9	1.99	616.46	343.31	649.95	4858.68	12835.77	672.74	0.03	2153.99	460.52
1	2.20	617.92	344.77	652.59	4848.27	12804.52	693.58	0.03	2153.99	460.52
6.93	14.94386023	707.7200612	434.5700612	814.2261102	4216.50503	10909.23508	1957.0999	0.099359	2153.99	460.52
6.94	14.96789187	707.8909293	434.7409293	814.5336728	4215.3137	10905.66111	1959.4826	0.099492	2153.99	460.52
6.95	**14.99193353**	**708.0618745**	**434.9118745**	**814.8413741**	**4214.12188**	**10902.08564**	**1961.8662**	**0.099625**	**2153.99**	**460.52**
6.96	15.01598517	708.2328966	435.0828966	815.1492138	4212.92956	10898.50869	1964.2509	0.099758	2153.99	460.52
6.97	15.04004677	708.4039954	435.2539954	815.4571916	4211.73675	10894.93026	1966.6365	0.099891	2153.99	460.52
18.4	27.82	800.08	526.93	980.47	3578.31	8994.66	3233.48	0.18	2153.99	460.52
18.5	27.82	800.08	526.93	980.48	3578.29	8994.58	3233.54	0.18	2153.99	460.52
18.6	27.82	800.09	526.94	980.49	3578.26	8994.51	3233.58	0.18	2153.99	460.52
18.7	27.82	800.09	526.94	980.49	3578.24	8994.45	3233.63	0.18	2153.99	460.52

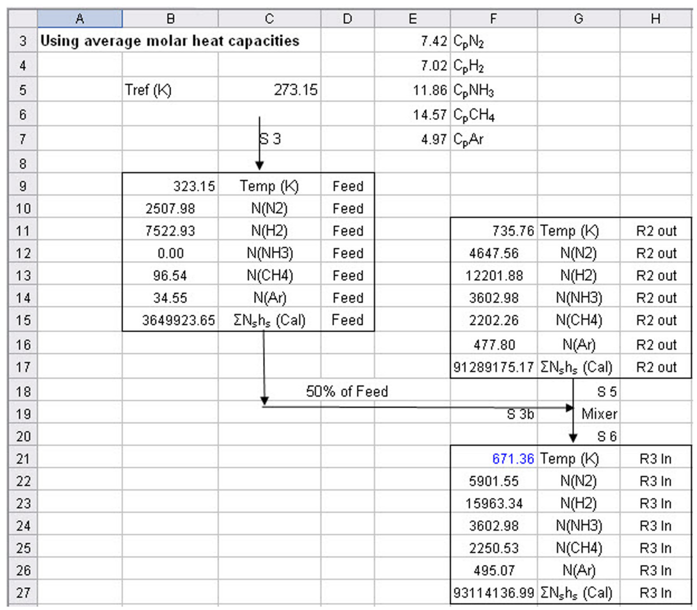
(c)

FIGURE p5.5bc



	A	B	C	D	E	F	G	H	I	J	K	L
3	**Using average molar heat capacities**				7.42	C_pN_2						
4					7.02	C_pH_2						
5		Tref (K)	273.15		11.86	C_pNH_3						
6					14.57	C_pCH_4						
7			S 3		4.97	C_pAr						
8												
9		323.15	Temp (K)	Feed								
10		2507.98	N(N2)	Feed								
11		7522.93	N(H2)	Feed		708.06	Temp (K)	R1 out				
12		0.00	N(NH3)	Feed		4213.73	N(N2)	R1 out				
13		96.54	N(CH4)	Feed		10900.89	N(H2)	R1 out				
14		34.55	N(Ar)	Feed		1962.67	N(NH3)	R1 out				
15		3649923.65	$\Sigma N_s h_s$ (Cal)	Feed		2153.99	N(CH4)	R1 out				
16						460.52	N(Ar)	R1 out		Use Goal Seek to vary T R2 In		
17						71646977.43	$\Sigma N_s h_s$ (Cal)	R1 out		Energy Balance = 0 (out - in)		
18				50% of Feed			S 2			0		
19						S 3a	Mixer					
20							S 4					
21						638.25	Temp (K)	R2 In		689.18	Temp (F)	
22						5467.72	N(N2)	R2 In				
23						14662.35	N(H2)	R2 In				
24						1962.67	N(NH3)	R2 In				
25						2202.26	N(CH4)	R2 In				
26						477.80	N(Ar)	R2 In				
27						73471939.26	$\Sigma N_s h_s$ (Cal)	R2 In				

(a)



	A	B	C	D	E	F	G	H
3	**Using average molar heat capacities**				7.42	C_pN_2		
4					7.02	C_pH_2		
5		Tref (K)	273.15		11.86	C_pNH_3		
6					14.57	C_pCH_4		
7			S 3		4.97	C_pAr		
8								
9		323.15	Temp (K)	Feed				
10		2507.98	N(N2)	Feed				
11		7522.93	N(H2)	Feed		735.76	Temp (K)	R2 out
12		0.00	N(NH3)	Feed		4647.56	N(N2)	R2 out
13		96.54	N(CH4)	Feed		12201.88	N(H2)	R2 out
14		34.55	N(Ar)	Feed		3602.98	N(NH3)	R2 out
15		3649923.65	$\Sigma N_s h_s$ (Cal)	Feed		2202.26	N(CH4)	R2 out
16						477.80	N(Ar)	R2 out
17						91289175.17	$\Sigma N_s h_s$ (Cal)	R2 out
18				50% of Feed			S 5	
19						S 3b	Mixer	
20							S 6	
21						671.36	Temp (K)	R3 In
22						5901.55	N(N2)	R3 In
23						15963.34	N(H2)	R3 In
24						3602.98	N(NH3)	R3 In
25						2250.53	N(CH4)	R3 In
26						495.07	N(Ar)	R3 In
27						93114136.99	$\Sigma N_s h_s$ (Cal)	R3 In

(b)

FIGURE p5.6