SIMPLIFIED PROCESS SYNTHESIS OF DISTILLATION SEQUENCES

VOL 11

(APPENDICES)

by

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VOLUME II

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APPENDIX A

SOME TABLES OF RESULTS

TABLE A3.1: Sample results of variation of Total Annual Cost with R/R_m at various operating pressures.

Pressure = 0.066 Atm.

	TOTAL ANNUAL COST, DOLLARS		
R/R_m	α = 1.05	α = 1.20	α = 2.25
1.01	870568.7	116470.4	17064.4
1.02	807596.4	107170.5	15996.4
1.03	781148.3	103175.1	15533.7
1.04	767094.1	100980.2	15276.8
1.05	759047.0	99658.4	15119.9
1.06	754461.7	98839.8	15020.6
1.07	752091.1*	98343.3	14958.4
1.08	751240.7	98067.9*	14921.5
1.09	751488.1	97952.3	14903.0*
1.10	752559.5	97956.7	14898.4
1.20	784436.6	101083.8	15209.1
1.30	830500.2	106282.4	15761.7
1.40	881152.1	112153.6	16394.3
1.50	933921.9	18336.7	17064.6
1.60	987851.3	124691.3	17756.1

* Optimum Cost.

TABLE A3.1: (Continued)

Pressure = 0.352

	TOTAL ANNUAL COST, DOLLARS		
R/R_m	α = 1.05	α = 1.20	α = 2.25
1.01	399294.8	59410.9	9881.6
1.02	374015.3	55725.4	9463.6
1.03	363644.0	54203.1	9292.6
1.04	358331.7	53415.1	9205.5
1.05	355471.4	52983.1	9159.2
1.06	354024.1*	52756.4	9136.3*
1.07	353480.8	52661.0*	9128.6
1.08	353558.0	52655.8	9131.2
1.09	354083.4	52715.7	9141.3
1.10	354945.1	52824.6	9157.1
1.20	372200.4	55170.9	9460.2
1.30	395246.4	58362.0	9862.1
1.40	420165.3	61827.4	10296.6
1.50	445948.6	65420.0	10746.4
1.60	472205.3	69052.5	11204.9

α = Relative volatility

TABLE A3.1: (Continued)

Pressure = 1.000 Atm.

R/R_m	TOTAL ANNUAL COST, DOLLARS α = 1.05	 α = 1.20	 α = 2.25
1.01	275359.5	46699.5	8663.8
1.02	261413.8	44716.1	8446.6
1.03	255964.5	43964.7	8368.8
1.04	253398.5	43631.6	8338.2$_*$
1.05	252229.9$_*$	43501.2$_*$	8330.6
1.06	251866.6	43487.8	8336.5
1.07	252018.5	43549.1	8350.8
1.08	252524.1	43661.8	8370.9
1.09	253285.1	43811.6	8395.2
1.10	254237.7	43989.2	8422.8
1.20	268687.3	46482.0	8780.3
1.30	286437.1	49455.9	9193.5
1.40	305254.3	52586.1	9625.1
1.50	324564.1	55788.7	10065.4
1.60	344143.8	59031.1	10510.6

TABLE A3.1: (Continued)

Pressure = 1.690 Atm.

R/R_m	TOTAL ANNUAL COST, DOLLARS α = 1.05	 α = 1.20	 α = 2.25
1.01	245984.2	42646.0	8070.5
1.02	234074.6	40962.8	7887.8
1.03	229474.4	40339.0	7824.8
1.04	227354.7	40074.9$_*$	7802.4$_*$
1.05	226437.1$_*$	39985.1	7799.8
1.06	226212.4	39995.9	7808.6
1.07	226430.9	40071.0	7824.6
1.08	226953.7	40190.2	7845.7
1.09	227696.1	40341.4	7870.5
1.10	228603.5	40516.5	7897.9
1.20	241912.6	42883.8	8243.0
1.30	258060.8	45664.8	8636.0
1.40	275127.3	48580.1	9044.7
1.50	292617.6	51557.8	9460.9
1.60	310340.1	54569.7	9881.3

TABLE A3.1: (Continued)

Pressure = 5.000 Atm.

	TOTAL ANNUAL COST, DOLLARS		
R/R_m	$\alpha = 1.05$	$\alpha = 1.20$	$\alpha = 2.25$
1.01	141032.7	25423.1	5147.2
1.02	134698.8	24539.7	5054.5
1.03	132302.8	24226.4	5025.8*
1.04	131243.0	24106.6*	5018.8
1.05	130830.9*	24080.6	5022.4
1.06	130792.1	24108.6	5032.1
1.07	130992.0	24171.3	5045.7
1.08	131355.8	24257.8	5062.0
1.09	131838.0	24361.4	5080.3
1.10	132409.1	24477.9	5100.0
1.20	140401.2	22974.4	5334.7
1.30	149922.9	27693.5	5595.0
1.40	159939.3	29484.8	5863.8
1.50	170184.0	31309.7	6136.6
1.60	180553.7	33153.0	6411.5

TABLE A3.1: (Continued)

Pressure = 11.60 Atm.

	TOTAL ANNUAL COST, DOLLARS		
R/R_m	$\alpha = 1.05$	$\alpha = 1.20$	$\alpha = 2.25$
1.01	104131.4	19651.0	4210.2
1.02	99904.5	19072.4	4151.8
1.03	98354.9	18880.9*	4136.7*
1.04	97714.0*	18820.9	4136.7
1.05	97513.4	18834.6	4143.2
1.06	97566.5	18865.1	4154.2
1.07	97782.0	18929.1	4167.8
1.08	98109.0	19009.2	4183.2
1.09	98516.4	19101.0	4199.9
1.10	98984.3	19201.6	4217.6
1.20	105214.1	20432.2	4420.4
1.30	112483.9	21814.0	4640.4
1.40	120090.0	23244.9	4866.2
1.50	127851.4	24698.6	5094.6
1.60	135697.8	26164.9	5324.6

TABLE A3.1: (Continued)

Pressure = 15.50 Atm.

	TOTAL ANNUAL COST, DOLLARS		
R/R$_m$	α = 1.05	α = 1.20	α = 2.25
1.01	73825.4	14158.6	3275.2
1.02	70667.5	13727.5	3233.2
1.03	69490.3	13582.6	3223.1*
1.04	68985.1*	13534.9*	3223.0
1.05	68805.8	13534.4	3229.9
1.06	68814.1	13561.0	3239.1
1.07	68942.6	13605.0	3250.1
1.08	69153.9	13660.9	3262.5
1.09	69423.9	13725.4	3275.9
1.10	69739.0	13796.4	3290.0
1.20	74037.9	14673.0	3449.8
1.30	79106.1	15661.4	3622.3
1.40	84423.1	16686.1	3799.1
1.50	89855.0	17727.6	3977.9
1.60	95349.7	18778.4	4157.8

TABLE A3.1: (Continued)

Pressure = 20.00 Atm.

	TOTAL ANNUAL COST, DOLLARS		
R/R$_m$	α = 1.05	α = 1.20	α = 2.25
1.01	69091.1	13903.9	2829.7
1.02	66638.9	13578.9	2795.0*
1.03	65782.8	13484.6*	2787.0
1.04	65468.4*	13468.6	2788.2
1.05	65416.5	13490.6	2793.8
1.06	65515.9	13534.5	2801.9
1.07	65712.1	13592.4	2811.7
1.08	65974.7	13659.9	2822.6
1.09	66285.3	13734.3	2834.3
1.10	66632.0	13814.0	2846.6
1.20	71023.1	14744.6	2985.7
1.30	76034.1	15765.4	3135.4
1.40	81245.8	16815.4	3288.7
1.50	86549.9	17878.9	3443.6
1.60	91904.8	18950.0	3599.5

TABLE A3.2: Optimum values of R/R_m against the operating pressures, feed compositions and relative Volatilities.

P = 0.066

			R/R_m			
x_F	: α=1.05:	α =1.10:	α =1.20:	α=1.50:	α =2.25:	α =3.00:
0.10	1.0798	1.0866	1.0877	1.0818	1.0733	1.0711
0.25	1.0810	1.0884	1.0905	1.0870	1.0832	1.0850
0.50	1.0823	1.0907	1.0945	1.0951	1.0989	1.1071
0.75	1.0835	1.0928	1.0984	1.1034	1.1156	1.1312
0.90	1.0844	1.0945	1.1017	1.1109	1.1332	1.1612

P = 0.352

			R/R_m			
x_F	: α=1.05:	α=1.10:	α =1.20:	α =1.50:	α=2.25:	α =3.00:
0.10	1.0712	1.0732	1.0702	1.0617	1.0535	1.0512
0.25	1.0722	1.0747	1.0724	1.0656	1.0606	1.0612
0.50	1.0734	1.0766	1.0756	1.0717	1.0720	1.0771
0.75	1.0745	1.0784	1.0787	1.0779	1.0840	1.0943
0.90	1.0752	1.0798	1.0813	1.0834	1.0968	1.1157

P = 1.000 Atm.

			R/R_m			
x_F	: α =1.05:	α =1.10:	α =1.20:	α =1.50:	α=2.25:	α =3.00:
0.10	1.0595	1.0575	1.0523	1.0440	1.0371	1.0347
0.25	1.0604	1.0587	1.0540	1.0468	1.0420	1.0415
0.50	1.0614	1.0602	1.0563	1.0510	1.0498	1.0521
0.75	1.0623	1.0617	1.0587	1.0554	1.0582	1.0637
0.90	1.0630	1.0628	1.0606	1.0594	1.0669	1.0781

TABLE A3.2 (Continued)

P = 1.690 Atm.

	R/R_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.0576	1.0550	1.0497	1.0414	1.0347	1.0325
0.25	1.0584	1.0562	1.0512	1.0440	1.0394	1.0387
0.50	1.0594	1.0576	1.0535	1.0481	1.0467	1.0487
0.75	1.0602	1.0590	1.0557	1.0522	1.0545	1.0595
0.90	1.0609	1.0601	1.0575	1.0559	1.0627	1.0730

P = 5.00

	R/R_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.0544	1.0512	1.0455	1.0372	1.0302	1.0282
0.25	1.0553	1.0523	1.0469	1.0395	1.0343	1.0336
0.50	1.0562	1.0536	1.0490	1.0431	1.0406	1.0423
0.75	1.0570	1.0549	1.0510	1.0468	1.0474	1.0517
0.90	1.0576	1.0559	1.0527	1.0502	1.0545	1.0633

P = 11.60 Atm.

	R/R_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.0506	1.0467	1.0409	1.0327	1.0261	1.0244
0.25	1.0514	1.0477	1.0422	1.0348	1.0296	1.0291
0.50	1.0523	1.0489	1.0440	1.0380	1.0351	1.0365
0.75	1.0530	1.0501	1.0458	1.0412	1.0409	1.0446
0.90	1.0536	1.0510	1.0473	1.0442	1.0470	1.0547

TABLE A3.2 (Continued)

$P = 15.50$ Atm.

	R/R_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.0526	1.0484	1.0417	1.0325	1.0250	1.0234
0.25	1.0534	1.0494	1.0431	1.0345	1.0284	1.0279
0.50	1.0543	1.0507	1.0449	1.0377	1.0336	1.0351
0.75	1.0550	1.0519	1.0468	1.0409	1.0392	1.0429
0.90	1.0556	1.0528	1.0483	1.0438	1.0451	1.0525

$P = 20.00$ Atm.

	R/R_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.0462	1.0416	1.0355	1.0290	1.0245	1.0231
0.25	1.0469	1.0425	1.0366	1.0308	1.0277	1.0276
0.50	1.0477	1.0436	1.0382	1.0336	1.0329	1.0347
0.75	1.0484	1.0446	1.0398	1.0365	1.0383	1.0423
0.90	1.0489	1.0455	1.0411	1.0391	1.0441	1.0519

TABLE A3.3: Optimum values of R/R_m against the recovery fractions.

P = 0.066 Atm.

	R/R_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.0859	1.0919	1.0930	1.0906	1.0921	1.0987
0.95	1.0848	1.0916	1.0935	1.0921	1.0941	1.1012
0.99	1.0823	1.0907	1.0945	1.0951	1.0989	1.1071

P = 0.352 Atm.

	R/R_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.0748	1.0756	1.0725	1.0669	1.0659	1.0700
0.95	1.0744	1.0760	1.0736	1.0685	1.0679	1.0723
0.99	1.0734	1.0766	1.0756	1.0717	1.0720	1.0771

P = 1.00 Atm.

	R/R_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.0610	1.0580	1.0531	1.0471	1.0454	1.0471
0.95	1.0612	1.0588	1.0542	1.0484	1.0468	1.0487
0.99	1.0614	1.0602	1.0563	1.0510	1.0498	1.0521

P = 1.69 Atm.

	R/R_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.0587	1.0553	1.0502	1.0443	1.0424	1.0439
0.95	1.0590	1.0561	1.0513	1.0455	1.0438	1.0455
0.99	1.0594	1.0576	1.0535	1.0481	1.0467	1.0487

TABLE A3.3 (Continued)

P = 5.00 Atm.

	R/R_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.0553	1.0513	1.0459	1.0397	1.0369	1.0381
0.95	1.0556	1.0521	1.0469	1.0408	1.0381	1.0394
0.99	1.0562	1.0536	1.0490	1.0431	1.0406	1.0423

P = 11.60 Atm.

	R/R_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.0509	1.0465	1.0410	1.0348	1.0316	1.0326
0.95	1.0514	1.0473	1.0420	1.0358	1.0327	1.0339
0.99	1.0523	1.0489	1.0440	1.0380	1.0531	1.0365

P = 15.50 Atm.

	R/R_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.0535	1.0486	1.0422	1.0347	1.0304	1.0313
0.95	1.0537	1.0492	1.0431	1.0356	1.0314	1.0326
0.99	1.0543	1.0507	1.0449	1.0377	1.0336	1.0351

P = 20.00 Atm.

	R/R_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.0460	1.0410	1.0353	1.0306	1.0293	1.0306
0.95	1.0466	1.0419	1.0363	1.0316	1.0305	1.0320
0.99	1.0477	1.0436	1.0382	1.0336	1.0329	1.0347

TABLE A3.4: Optimum values of R/R_m [Carbon Steel] against the operating pressures.

	R/R_m					
P,Atm.	α =1.05	α=1.10	α =1.20	α =1.50	α=2.25	α =3.00
0.066	1.0823	1.0907	1.09445	1.0951	1.0989	1.1071
0.352	1.0734	1.0766	1.0756	1.0717	1.0720	1.0771
1.000	1.0614	1.0602	1.0563	1.0510	1.0498	1.0521
1.690	1.0594	1.0576	1.0535	1.0481	1.0467	1.0487
5.000	1.0562	1.0536	1.0490	1.0431	1.0406	1.0423
11.60	1.0523	1.0489	1.0440	1.0380	1.0351	1.0365
15.50	1.0543	1.0507	1.0449	1.0377	1.0336	1.0351
20.00	1.0477	1.0436	1.0382	1.0336	1.0329	1.0347

TABLE A3.5: Optimum values of R/R_m [Stainless Steel] against the operating pressures.

	R/R_m					
P,Atm.	α =1.05	α=1.10	α =1.20	α =1.50	α =2.25	α =3.00
0.066	1.0954	1.1152	1.1346	1.1576	1.1824	1.2062
0.352	1.0914	1.1070	1.1197	1.1306	1.1423	1.1573
1.000	1.0854	1.0959	1.1020	1.1050	1.1107	1.1183
1.690	1.0841	1.0937	1.0987	1.1005	1.1049	1.1117
5.000	1.0816	1.0893	1.0921	1.0904	1.0885	1.0924
11.60	1.0788	1.0847	1.0854	1.0815	1.0772	1.0807
15.50	1.0803	1.0865	1.0868	1.0810	1.0741	1.0777
20.00	1.0740	1.0786	1.0736	1.0700	1.0715	1.0765

TABLE A3.6: Optimum values of R/R_m at Zero-Energy cost against the operating pressure and relative volatility

α	Pressure, Atm	R/R_m
1.05	1.066	1.2010
	0.352	1.2001
	1.000	1.2000
	1.690	1.2000
	5.000	1.1984
	11.60	1.1978
	15.50	1.1982
	20.00	1.1941
1.10	0.066	1.2277
	0.352	1.2255
	1.000	1.2247
	1.690	1.2243
	5.000	1.2215
	11.60	1.2201
	15.50	1.2209
	20.00	1.2111
1.20	0.066	1.2601
	0.352	1.2550
	1.000	1.2535
	1.690	1.2528
	5.000	1.2463
	11.60	1.2432
	15.50	1.2442
	20.00	1.2215
1.50	0.066	1.2739
	0.352	1.2000
	1.000	1.2000
	1.690	1.1964
	5.000	1.2073
	11.60	1.2694
	15.50	1.2691
	20.00	1.2346

TABLE A3.6 (Continued)

α	Pressure, Atm	R/R_m
2.25	0.066	1.2825
	0.352	1.2469
	1.000	1.2557
	1.690	1.2516
	5.000	1.2420
	11.60	1.2714
	15.50	1.2644
	20.00	1.2531
3.00	0.066	1.3420
	0.352	1.2911
	1.000	1.2936
	1.690	1.2882
	5.000	1.2705
	11.60	1.2803
	15.50	1.2751
	20.00	1.2701

TABLE A3.7: Optimum values of the Total Annual Cost (TAC) per moles of distillate against the operating pressures, feed compositions and relative volatilities

P = 0.066

	TOTAL ANNUAL COST PER MOLES OF DISTILLATE					
x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.10	3703939	1239646	458663	143703	53009	33427
0.25	1492491	502958	188546	61301	24504	16503
0.50	751212	255938	97941	33633	14898	10775
0.75	496714	171007	66703	24012	11482	8691
0.90	390845	135349	53349	19678	9749	7516

P = 0.352 Atm.

	TOTAL ANNUAL COST PER MOLES OF DISTILLATE					
x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.10	1743298	622963	246511	83323	32324	20733
0.25	702303	252690	101324	35564	14970	10264
0.50	353447	128580	52648	19538	9128	6727
0.75	233699	85920	35873	13969	7054	5444
0.90	183889	68013	28704	11462	6003	4723

P = 1.000 Atm.

	TOTAL ANNUAL COST PER MOLES OF DISTILLATE					
x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.10	1242814	480318	203552	73231	29379	19253
0.25	500529	194771	83657	31272	13628	9555
0.50	251861	99104	43482	17201	8330	6282
0.75	166523	66231	29642	12314	6452	5098
0.90	131032	52435	23728	10116	5502	4435

TABLE A3.7 (Continued)

P = 1.690 Atm.

TOTAL ANNUAL COST PER MOLES OF DISTILLATE

x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1116333	436957	187150	68026	27485	18065
0.25	449567	177180	76915	29052	12754	8968
0.50	226211	90152	39979	15982	7799	5899
0.75	149563	50250	27256	11444	6042	4789
0.90	117687	47701	21820	9402	5154	4167

P = 5.00 Atm.

TOTAL ANNUAL COST PER MOLES OF DISTILLATE

x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	645433	258019	112717	42071	17669	11734
0.25	259906	104615	46323	17969	8201	5829
0.50	130773	53229	24080	9888	5018	3837
0.75	86462	35575	16418	7083	3891	3117
0.90	68034	28166	13145	5821	3321	2715

P = 11.60 Atm.

TOTAL ANNUAL COST PER MOLES OF DISTILLATE

x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	481323	197242	88074	33732	14543	9669
0.25	193802	79966	36194	14409	6753	4806
0.50	97507	40687	18816	7932	4135	3166
0.75	64467	27193	12831	5683	3207	2574
0.90	50727	21531	10274	4672	2739	2243

TABLE A3.7 (Continued)

P = 15.50 Atm.

TOTAL ANNUAL COST PER MOLES OF DISTILLATE						
x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.10	339546	139520	63331	25183	11330	7533
0.25	136723	56566	26026	10758	5262	3745
0.50	68791	28781	13530	5922	3222	2468
0.75	45481	19236	9226	4243	2500	2006
0.90	35788	15230	7387	3488	2135	1748

P = 20.00 Atm.

TOTAL ANNUAL COST PER MOLES OF DISTILLATE						
x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.10	322951	136524	63035	23917	9796	6437
0.25	130019	55344	25903	10218	4550	3200
0.50	65412	28159	13468	5626	2786	2109
0.75	43246	18821	9185	4032	2162	1714
0.90	34029	14902	7356	3315	1846	1494

TABLE A3.8: Correction factor, Fr2, on the optimum values of R/R_m for stainless steel material.

		R/R_m		
α	P, Atm.	C. S	S. S	Fr2
1.05	0.066	1.0823	1.0954	1.013
	0.352	1.0734	1.0914	1.018
	1.000	1.0614	1.0854	1.023
	1.690	1.0594	1.0841	1.023
	5.000	1.0562	1.0816	1.024
	11.69	1.0523	1.0788	1.025
	15.50	1.0543	1.0802	1.025
	20.00	1.0477	1.0740	1.025
1.10	0.066	1.0907	1.1152	1.022
	0.352	1.0766	1.1070	1.028
	1.000	1.0602	1.0959	1.034
	1.690	1.0576	1.0937	1.034
	5.000	1.0536	1.0893	1.034
	11.69	1.0489	1.0847	1.034
	15.50	1.0507	1.0865	1.034
	20.00	1.0436	1.0768	1.032
1.20	0.066	1.0945	1.1346	1.037
	0.352	1.0756	1.1197	1.041
	1.000	1.0563	1.1020	1.043
	1.690	1.0535	1.0987	1.043
	5.000	1.0490	1.0921	1.042
	11.60	1.0440	1.0854	1.040
	15.50	1.0449	1.0868	1.040
	20.00	1.0382	1.0736	1.034
1.50	0.066	1.0951	1.1576	1.057
	0.352	1.0717	1.1306	1.055
	1.000	1.0510	1.1050	1.051
	1.690	1.0481	1.1005	1.050
	5.000	1.0431	1.0904	1.045
	11.60	1.0380	1.0815	1.042
	15.50	1.0377	1.0810	1.042
	20.00	1.0336	1.0700	1.035

C. S.	Carbon steel material
C. S.	Stainless steel material
Fr2	$(R/R_m)_{Stainless} / (R/R_m)_{Carbon}$

TABLE A3.8 (Continued)

α	P, Atm.	R/R_m		
		C. S	S. S	Fr2
2.25	0.066	1.0989	1.1824	1.076
	0.352	1.0720	1.1423	1.066
	1.000	1.0498	1.1107	1.058
	1.690	1.0467	1.1049	1.056
	5.000	1.0406	1.0885	1.046
	11.60	1.0351	1.0772	1.041
	15.50	1.0336	1.0741	1.039
	20.00	1.0329	1.0715	1.037
3.00	0.066	1.1071	1.2062	1.090
	0.352	1.0771	1.1573	1.074
	1.000	1.0521	1.1183	1.063
	1.690	1.0487	1.1117	1.060
	5.000	1.0423	1.0924	1.048
	11.60	1.0365	1.0807	1.043
	15.50	1.0351	1.0777	1.041
	20.00	1.0347	1.0756	1.040

TABLE A3.9: Correction factor, Fc2, on the optimum values of Total Annual cost (TAC)/Energy cost (EC) for stainless-steel.

		TOTAL ANNUAL COST / ENERGY COST		
α	P, Atm.	C. S	S. S	Fc2
1.05	0.066	4.579	15.121	3.302
	0.352	3.198	9.612	3.006
	1.000	2.252	5.851	2.598
	1.690	2.147	5.437	2.532
	5.000	2.025	4.954	2.446
	11.60	1.875	4.360	2.325
	15.50	1.945	4.638	2.385
	20.00	1.772	3.960	3.235
1.10	0.066	3.027	8.889	2.937
	0.352	2.266	6.871	2.591
	1.000	1.732	3.767	2.175
	1.690	1.673	3.536	2.114
	5.000	1.608	3.285	2.043
	11.60	1.522	2.952	1.940
	15.50	1.550	3.063	1.976
	20.00	1.479	2.796	1.890
1.20	0.066	2.211	5.611	2.538
	0.352	1.775	3.909	2.202
	1.000	1.455	2.669	1.834
	1.690	1.420	2.535	1.785
	5.000	1.386	2.410	1.739
	11.60	1.333	2.213	1.660
	15.50	1.342	2.245	1.673
	20.00	1.332	2.225	1.670
1.50	0.066	1.681	3.507	2.086
	0.352	1.458	2.664	1.827
	1.000	1.270	1.955	1.539
	1.690	1.250	1.883	1.506
	5.000	1.240	1.853	1.494
	11.60	1.210	1.747	1.444
	15.50	1.208	1.739	1.440
	20.00	1.231	1.740	1.413

TABLE A3.9 (Continued)

		$\frac{\text{TOTAL ANNUAL COST}}{\text{ENERGY COST}}$		
α	P, Atm.	C. S	S. S	Fc2
2.25	0.066	1.448	2.612	1.804
	0.352	1.321	2.149	1.627
	1.000	1.181	1.630	1.380
	1.690	1.169	1.585	1.356
	5.000	1.186	1.669	1.407
	11.60	1.171	1.618	1.382
	15.50	1.169	1.614	1.380
	20.00	1.178	1.651	1.401
3.00	0.066	1.371	2.326	1.697
	0.352	1.273	1.975	1.551
	1.000	1.155	1.540	1.333
	1.690	1.144	1.509	1.313
	5.000	1.176	1.640	1.394
	11.60	1.162	1.592	1.370
	15.50	1.158	1.580	1.364
	20.00	1.161	1.592	1.371

C. S. Carbon steel material
C. S. Stainless steel material
Fc2 $(TAC/EC)_{Stainless} / (TAC/EC)_{Carbon}$

TABLE A3.10: Optimum values of N/N_m against the operating pressures, feed compositions and Relative Volatilities

P = 0.066

x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
	N/N_m					
0.10	1.339	1.473	1.673	2.082	2.689	3.057
0.25	1.341	1.476	1.675	2.072	2.633	2.950
0.50	1.343	1.477	1.671	2.047	2.548	2.805
0.75	1.343	1.476	1.665	2.021	2.467	2.684
0.90	1.343	1.474	1.659	1.999	2.397	2.567

P = 0.352 Atm

x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
	N/N_m					
0.10	1.354	1.505	1.733	2.204	2.904	3.329
0.25	1.357	1.508	1.734	2.193	2.841	3.207
0.50	1.358	1.508	1.730	2.166	2.743	3.045
0.75	1.359	1.507	1.724	2.137	2.655	2.908
0.90	1.358	1.505	1.718	2.113	2.577	2.777

P = 1.000 Atm.

x_F	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
	N/N_m					
0.10	1.378	1.553	1.819	2.369	3.187	3.698
0.25	1.381	1.556	1.820	2.356	3.115	3.559
0.50	1.383	1.557	1.816	2.326	3.004	3.372
0.75	1.384	1.555	1.809	2.293	2.903	3.214
0.90	1.383	1.554	1.802	2.266	2.814	3.062

TABLE A3.10 (continued)

P = 1.690 Atm.

	N/N_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.383	1.562	1.835	2.400	3.241	3.768
0.25	1.386	1.565	1.837	2.387	3.168	3.625
0.50	1.388	1.566	1.832	2.356	3.054	3.434
0.75	1.389	1.565	1.825	2.323	2.951	3.271
0.90	1.388	1.563	1.818	2.295	2.860	3.116

P = 5.000 Atm.

	N/N_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.391	1.578	1.863	2.459	3.363	3.920
0.25	1.395	1.581	1.865	2.445	3.285	3.769
0.50	1.396	1.582	1.860	2.413	3.165	3.567
0.75	1.397	1.580	1.853	2.379	3.057	3.397
0.90	1.397	1.578	1.846	2.349	2.961	3.233

P = 11.60 Atm.

	N/N_m					
x_F	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.10	1.402	1.598	1.899	2.531	3.498	4.086
0.25	1.406	1.602	1.901	2.516	3.416	3.927
0.50	1.407	1.602	1.896	2.483	3.289	3.714
0.75	1.408	1.601	1.888	2.447	3.175	3.533
0.90	1.408	1.599	1.881	2.416	3.073	3.360

TABLE A3.10 (Continued)

P = 15.50 Atm.

	N/N$_m$					
x_F	α =1.05	α =1.10	α=1.20	α =1.50	α =2.25	α=3.00
0.10	1.397	1.590	1.892	2.535	3.537	4.133
0.25	1.400	1.594	1.894	2.521	3.454	3.972
0.50	1.402	1.594	1.889	2.487	3.325	3.755
0.75	1.402	1.593	1.881	2.451	3.209	3.572
0.90	1.402	1.591	1.874	2.420	3.106	3.397

P = 20.00 Atm.

	N/N$_m$					
x_F	α =1.05	α =1.10	α=1.20	α =1.50	α =2.25	α=3.00
0.10	1.416	1.625	1.948	2.603	3.559	4.147
0.25	1.420	1.628	1.950	2.588	3.475	3.985
0.50	1.422	1.629	1.945	2.553	3.346	3.768
0.75	1.422	1.627	1.937	2.515	3.229	3.584
0.90	1.422	1.626	1.929	2.483	3.125	3.408

TABLE A3.11: Optimum values of N/N_m against the Recovery Fraction, x_R

P = 0.066

	N/N_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.393	1.553	1.788	2.252	2.881	3.221
0.95	1.376	1.526	1.747	2.180	2.762	3.072
0.99	1.343	1.477	1.671	2.047	2.546	2.805

P = 0.352

	N/N_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.414	1.596	1.866	2.404	3.134	3.530
0.95	1.395	1.565	1.818	2.320	2.994	3.355
0.99	1.358	1.508	1.730	2.166	2.743	3.045

P = 1.000 Atm.

	N/N_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.448	1.658	1.975	2.603	3.458	3.938
0.95	1.425	1.622	1.919	2.505	3.295	3.734
0.99	1.383	1.557	1.816	2.326	3.004	3.372

P = 1.690 Atm.

	N/N_m					
x_R	α=1.05	α=1.10	α=1.20	α=1.50	α=2.25	α=3.00
0.90	1.454	1.670	1.996	2.642	3.522	4.018
0.95	1.431	1.633	1.938	2.540	3.354	3.807
0.99	1.388	1.566	1.832	2.356	3.054	3.434

TABLE A3.11 (Continued)

P = 5.000 Atm.

	N/N_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.465	1.690	2.030	2.711	3.660	4.186
0.95	1.441	1.652	1.970	2.605	3.483	3.962
0.99	1.396	1.582	1.860	2.413	3.165	3.567

P = 11.60 Atm.

	N/N_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.479	1.716	2.075	2.800	3.821	4.378
0.95	1.454	1.676	2.012	2.687	3.629	4.136
0.99	1.407	1.602	1.892	2.483	3.289	3.714

P = 15.50 Atm.

	N/N_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.470	1.704	2.063	2.801	3.862	4.431
0.95	1.447	1.666	2.002	2.690	3.670	4.185
0.99	1.402	1.594	1.889	2.487	3.325	3.755

P = 20.00 Atm.

	N/N_m					
x_R	$\alpha=1.05$	$\alpha=1.10$	$\alpha=1.20$	$\alpha=1.50$	$\alpha=2.25$	$\alpha=3.00$
0.90	1.498	1.751	2.137	2.890	3.900	4.462
0.95	1.471	1.708	2.069	2.769	3.699	4.208
0.99	1.422	1.629	1.945	2.553	3.346	3.768

TABLE A3.12: Optimum values of N/N_m [Carbon steel] against the operating pressures, P

	N/N_m					
P, Atm:	α =1.05:	α =1.10:	α=1.20:	α =1.50:	α =2.25:	α=3.00:
0.066	1.343	1.477	1.671	2.047	2.546	2.805
0.352	1.358	1.508	1.730	2.166	2.743	3.045
1.000	1.383	1.557	1.816	2.326	3.004	3.372
1.690	1.388	1.566	1.832	2.356	3.054	3.434
5.000	1.396	1.582	1.860	2.413	3.165	3.567
11.60	1.407	1.602	1.896	2.483	3.289	3.717
15.50	1.402	1.594	1.889	2.487	3.325	3.755
20.00	1.422	1.629	1.945	2.553	3.346	3.768

TABLE A3.13: Optimum values of N/N_m [Stainless steel] against the operating pressures, P

	N/N_m					
P, Atm:	α =1.05:	α=1.10:	α =1.20:	α =1.50:	α=2.25:	α=3.00:
0.066	1.324	1.435	1.587	1.865	2.226	2.409
0.352	1.330	1.448	1.613	1.929	2.347	2.561
1.000	1.338	1.467	1.652	2.009	2.481	2.739
1.690	1.340	1.471	1.660	2.026	2.512	2.777
5.000	1.344	1.479	1.677	2.068	2.612	2.909
11.60	1.349	1.489	1.695	2.111	2.698	3.010
15.50	1.346	1.485	1.693	2.113	2.725	3.039
20.00	1.357	1.508	1.737	2.176	2.748	3.051

TABLE A4.1: Total Annual Cost(TAC) of Sequences of a five-component feedstock No. 1

A:	Propane	2.5024**
B:	I-Butane	1.3714
C:	N-Butane	2.4140
D:	I-Pentane	1.2872
E:	N-Pentane	

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order*
1	1	144476	753211	897687	0.839	13
	2	137850	709070	846920	0.837	3
	3	129672	707741	837414	0.845	1
	4	143455	735234	878669	0.837	7
	5	139088	722833	861922	0.839	4
	6	126055	748688	874744	0.856	5
	7	120363	721835	842198	0.857	2
	8	124165	752293	876458	0.858	6
	9	128511	764693	893205	0.856	11
	10	128018	762753	890772	0.856	10
	11	143961	749627	893588	0.839	12
	12	133779	751862	885642	0.849	8
	13	135742	765928	901670	0.849	14
	14	136298	751883	8888181	0.847	9

TABLE A4.1: (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
1	1	82555	444337	526893	0.843	4
	2	87434	464031	551466	0.841	7
	3	83345	463367	546713	0.848	6
	4	87946	481332	569278	0.846	10
	5	94193	502385	596578	0.843	12
	6	76518	479860	556378	0.862	8
	7	82007	502160	584168	0.860	11
	8	90059	551189	641248	0.860	14
	9	83812	530136	613948	0.863	13
	10	77499	486893	564392	0.863	9
	11	82298	442545	524844	0.843	3
	12	77207	443663	520871	0.852	1
	13	78189	450696	528885	0.852	5
	14	78466	443673	522140	0.850	2

* order in terms of total annual cost
** Relative volatility

TABLE A4.1: (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
3	1	129322	697644	826967	0.844	4
	2	126264	677290	803555	0.843	2
	3	122175	676626	798802	0.847	1
	4	142043	778138	920182	0.846	9
	5	139939	775046	914985	0.847	8
	6	135740	758691	894431	0.848	6
	7	133057	743623	876681	0.848	5
	8	148408	857448	1005857	0.852	11
	9	150512	860541	1011053	0.851	14
	10	150057	857046	1007103	0.851	12
	11	142138	789893	932031	0.848	10
	12	136533	760862	897395	0.848	7
	13	150851	859216	1010067	0.851	13
	14	125233	696980	822214	0.848	3

TABLE A4.1: (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
4	1	135034	763888	898922	0.850	6
	2	119551	686482	806033	0.852	1
	3	132197	756194	888391	0.851	4
	4	133905	750781	884686	0.849	3
	5	119801	689786	809587	0.852	2
	6	147266	840975	988242	0.851	10
	7	132349	772658	905007	0.854	7
	8	133932	791458	925390	0.855	8
	9	148036	852452	1000489	0.852	13
	10	148080	849703	997783	0.852	11
	11	134408	759232	893641	0.850	5
	12	149225	842495	991720	0.850	12
	13	150038	851222	1001261	0.850	14
	14	147680	833600	981280	0.850	9

TABLE A4.1: (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
5	1	201340	1005681	1207022	0.833	12
	2	194452	928517	1122970	0.827	6
	3	191328	933794	1125123	0.830	7
	4	189638	884133	1073771	0.823	3
	5	187465	877932	1065398	0.824	1
	6	178045	1009525	1187570	0.850	11
	7	171847	949530	1121377	0.847	5
	8	165910	905105	1071016	0.845	2
	9	168083	911305	1079389	0.844	4
	10	171417	966897	1138315	0.849	8
	11	193562	953837	1147400	0.831	9
	12	192413	1015253	1207667	0.841	13
	13	185785	972625	1158411	0.840	10
	14	198217	1010957	1209175	0.836	14

TABLE A4.1: (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
6	1	177107	916595	1093702	0.838	14
	2	169999	845930	1015929	0.833	12
	3	142898	773235	916134	0.844	6
	4	167041	805670	972711	0.828	10
	5	164868	799470	964338	0.829	9
	6	116318	717560	833879	0.861	2
	7	113472	704134	817607	0.861	1
	8	115373	719363	834736	0.862	3
	9	117546	725563	843110	0.861	5
	10	117300	724593	841893	0.861	4
	11	171054	869545	1040599	0.836	13
	12	134794	790454	925248	0.854	7
	13	135775	797486	933262	0.855	8
	14	150006	843900	993907	0.849	11

TABLE A4.2: Total Annual Cost(TAC) of Sequences of a five-component feedstock No. 2

A:	I-Butane	1.9102
B:	Neo-Pentane	2.2308
C:	N-Pentane	2.2166
D:	2-Methyl Pentane	1.9992
E:	Cyclohexane	

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
1	1	76785	547469	624254	0.877	6
	2	76483	524642	601126	0.873	1
	3	80915	539133	620048	0.870	5
	4	78279	524223	602503	0.870	2
	5	80078	535134	615213	0.870	3
	6	85423	564491	649915	0.869	10
	7	85918	558599	644518	0.867	8
	8	91055	587765	678220	0.866	14
	9	89256	576854	666110	0.866	13
	10	88226	572867	661093	0.867	12
	11	78216	537773	615990	0.873	4
	12	84962	563114	648077	0.869	9
	13	87765	571490	659256	0.867	11
	14	51216	561960	643176	0.874	7

TABLE A4.2 (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
2	1	60254	388266	448520	0.866	2
	2	72271	453744	526016	0.863	9
	3	74487	460989	535477	0.861	10
	4	69946	419088	489034	0.857	8
	5	83125	494712	577838	0.856	13
	6	72019	409103	481122	0.850	6
	7	84426	479950	564376	0.850	12
	8	96122	531798	627921	0.847	14
	9	82943	456174	539117	0.846	11
	10	73420	413291	486711	0.849	7
	11	60970	383418	444388	0.863	1
	12	64343	396088	460431	0.860	4
	13	65744	400276	466021	0.859	5
	14	62470	395511	457981	0.864	3

TABLE A4.2 (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
3	1	75048	498778	573826	0.869	2
	2	74850	479320	554171	0.865	1
	3	77066	486566	563632	0.863	3
	4	90549	559107	649656	0.861	8
	5	91518	562719	654238	0.860	9
	6	91939	552152	644091	0.857	6
	7	92295	545724	638020	0.855	5
	8	109724	633714	743438	0.852	12
	9	108755	630101	738857	0.853	11
	10	107835	633351	741187	0.855	14
	11	90023	568725	658748	0.863	10
	12	91093	555686	646779	0.859	7
	13	106989	636885	743874	0.856	13
	14	77264	506023	583287	0.868	4

TABLE A4.2 (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
4	1	83559	578029	661589	0.874	5
	2	77118	517698	594816	0.870	1
	3	99030	625893	724923	0.863	6
	4	85032	562320	647352	0.869	3
	5	79713	520476	600189	0.867	2
	6	109094	683362	792457	0.862	10
	7	103060	630950	734010	0.860	7
	8	106233	643264	749498	0.858	8
	9	111553	685108	796661	0.860	12
	10	111219	687128	798347	0.861	13
	11	85083	572828	657911	0.871	4
	12	107721	685131	792853	0.864	11
	13	109847	688897	798744	0.862	14
	14	105472	686224	791698	0.867	9

TABLE A4.2 (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
5	1	96777	708253	805031	0.888	11
	2	93506	650199	743705	0.874	6
	3	96030	658385	754415	0.873	7
	4	86256	593815	680072	0.873	1
	5	87156	599271	686427	0.873	2
	6	102907	717240	820147	0.875	13
	7	100028	667967	767995	0.870	10
	8	94339	625257	719597	0.869	4
	9	93440	619802	713242	0.869	3
	10	97542	664354	761896	0.872	8
	11	90811	646918	737730	0.877	5
	12	101302	719440	820743	0.877	14
	13	95937	666554	762492	0.874	9
	14	99301	716440	815741	0.878	12

TABLE A4.2 (Continued)

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
6	1	68395	577797	646192	0.894	14
	2	66279	521067	587346	0.887	12
	3	60360	461094	521454	0.884	6
	4	63369	477605	540974	0.883	9
	5	64269	483060	547329	0.883	10
	6	55713	420389	476102	0.883	2
	7	55961	417443	473404	0.882	1
	8	58529	432026	490555	0.881	5
	9	57629	426570	484200	0.881	4
	10	57114	424577	481692	0.881	3
	11	65761	528714	594476	0.889	13
	12	59888	467054	526943	0.886	7
	13	61290	471242	532533	0.885	8
	14	62476	517825	580301	0.892	11

TABLE A4.3: Total Annual Cost (TAC) of Sequences of a Four-component feedstock No. 1

A: I-Butane 3.3104
B: I-Pentane 3.8201
C: N-Hexane 2.8736
D: N-Heptane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	42600	376651	419251	0.900	2
	2	43636	360599	404236	0.890	1
	3	48738	372087	420825	0.880	3
	4	50623	376345	426968	0.880	5
	5	46910	378612	425523	0.890	4
2	1	31561	208813	240375	0.870	1
	2	42171	262894	305065	0.862	4
	3	43023	248472	291495	0.852	3
	4	53938	301313	355251	0.848	5
	5	33938	209598	242883	0.863	2
3	1	44403	339344	383748	0.884	2
	2	44475	324321	368796	0.879	1
	3	64000	407387	471387	0.864	4
	4	64529	405303	469833	0.863	3
	5	63068	415661	478729	0.852	5
4	1	57714	497626	555340	0.896	4
	2	54210	437683	491894	0.890	1
	3	61056	487609	548665	0.889	3
	4	57923	438346	496269	0.885	2
	5	59745	499106	558851	0.893	5
5	1	36099	474031	510130	0.929	5
	2	34500	404929	439430	0.922	4
	3	29188	309879	339067	0.914	1
	4	29941	311583	341524	0.912	2
	5	32509	397931	430441	0.924	3

TABLE A4.4: Total Annual Cost (TAC) of Sequences of a Four-component feedstock No. 2

A: I-Butane 1.3714
B: N-Butane 3.1073
C: N-Pentane 2.9678
D: N-Hexane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	78179	487913	566092	0.862	2
	2	78239	480530	558760	0.860	1
	3	81948	494375	576323	0.857	3
	4	84243	508326	592569	0.858	5
	5	80717	496353	577070	0.860	4
2	1	93715	498386	592101	0.842	1
	2	106079	579802	685882	0.845	4
	3	104528	537531	642059	0.837	3
	4	118745	628603	747348	0.841	5
	5	94730	501762	596492	0.841	2
3	1	97596	559970	657566	0.852	2
	2	97055	552720	649776	0.851	1
	3	111693	628252	739945	0.849	3
	4	112335	631476	743811	0.849	5
	5	111151	631198	742349	0.850	4
4	1	70470	480552	551022	0.872	3
	2	64102	428051	492153	0.870	1
	3	72558	479979	552537	0.869	4
	4	66817	436955	503772	0.867	2
	5	72251	480941	553193	0.869	5
5	1	48584	426573	475158	0.898	5
	2	45020	368744	413765	0.891	3
	3	40352	315892	356245	0.887	1
	4	41270	321473	362743	0.886	2
	5	44530	372577	417108	0.893	4

TABLE A4.5: Total Annual Cost (TAC) of Sequences of a Four-component feedstock No. 3

A: 1-Butene 3.0955
B: 1-Pentene 1.2126
C: N-Pentane 2.9678
D: N-Hexane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy/Total	Order
1	1	189709	792634	979344	0.809	2
	2	159976	767339	927315	0.827	1
	3	190231	827741	1017972	0.813	5
	4	165964	818008	983973	0.831	3
	5	188102	819787	1007890	0.813	4
2	1	90814	421071	511885	0.822	1
	2	94787	460305	555093	0.829	3
	3	103207	486222	589429	0.825	4
	4	108459	540572	649032	0.833	5
	5	91371	420932	512304	0.822	2
3	1	279076	1085419	1364496	0.795	2
	2	270813	1080373	1351187	0.800	1
	3	302075	1228871	1530947	0.803	5
	4	294583	1233541	1528125	0.807	4
	5	300876	1227104	1527980	0.803	3
4	1	273508	1140412	1413921	0.807	3
	2	221796	1052832	1274628	0.826	1
	3	275198	1144976	1420174	0.806	4
	4	224662	1066436	1291099	0.826	2
	5	273545	1147959	1421504	0.808	5
5	1	100893	549843	650736	0.845	5
	2	85022	485561	570583	0.851	3
	3	84729	439730	524459	0.838	2
	4	75022	435837	510860	0.853	1
	5	88071	495421	583492	0.849	4

TABLE A4.6: Total Annual Cost (TAC) of Sequences of a Four-component feedstock No. 4

A: Trans-2-Butene 1.0776
B: Cis-2-Butene 2.8068
C: N-Pentane 2.9678
D: N-Hexane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	516577	1428634	1945212	0.734	4
	2	483872	1409171	1893043	0.744	1
	3	505160	1436576	1941736	0.740	2
	4	491768	1452305	1944073	0.747	3
	5	519630	1441534	1961165	0.735	5
2	1	793108	2004690	2797798	0.717	1
	2	767628	2087148	2854777	0.731	4
	3	789308	2060602	2849911	0.723	3
	4	783878	2177797	2961675	0.735	5
	5	794329	2009850	2804179	0.717	2
3	1	747698	2039053	2786751	0.732	2
	2	730119	2047312	2777431	0.737	1
	3	753793	2123961	2877754	0.738	4
	4	747221	2127317	2874538	0.740	3
	5	762593	2126826	2889420	0.736	5
4	1	260676	865819	1126496	0.769	3
	2	228382	813498	1041880	0.779	1
	3	261776	870885	1132661	0.769	5
	4	232303	810319	1042623	0.777	2
	5	262571	868793	1131364	0.768	4
5	1	237253	803433	1040686	0.772	5
	2	207355	728556	935912	0.778	3
	3	209807	682924	892731	0.765	1
	4	204450	689215	893666	0.771	2
	5	233336	751488	984825	0.763	4

TABLE A4.7: Total Annual Cost (TAC) of Sequences of a Four-component feedstock No. 5

A:	Propane	3.5254
B:	Trans-2-Butene	1.0776
C:	Cis-2-Butene	2.8068
D:	N-Pentane	

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	488839	1370767	1859606	0.737	3
	2	366568	1281245	1647813	0.778	1
	3	475919	1398398	1874317	0.746	5
	4	358426	1321055	1679482	0.787	2
	5	475511	1386261	1861773	0.745	4
2	1	205171	614076	819248	0.750	3
	2	151406	533318	684725	0.779	1
	3	206689	671706	878395	0.765	5
	4	155238	606735	761974	0.796	2
	5	199840	620274	820115	0.756	4
3	1	774147	2031560	2805708	0.724	2
	2	702880	2060656	2763536	0.745	1
	3	768798	2154552	2923350	0.737	5
	4	701365	2135614	2836980	0.753	3
	5	768654	2147864	2916522	0.736	4
4	1	737479	2083790	2821270	0.739	4
	2	543501	1939038	2482539	0.781	1
	3	730912	2093006	2823918	0.741	5
	4	538274	1956656	2494931	0.784	2
	5	730939	2087605	2818545	0.741	3
5	1	230431	774670	1005102	0.770	5
	2	173182	681317	854499	0.797	3
	3	197439	649908	847348	0.767	2
	4	150442	658972	809413	0.814	1
	5	201277	722121	923398	0.782	4

TABLE A4.8: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 1

A:	N-Butane	2.4140
B:	I-Pentane	1.2872
C:	N-Pentane	

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	156979	701975	858985	0.817	2
	2	142931	697381	840312	0.830	1
2	1	72340	364504	436845	0.834	1
	2	93806	472764	566570	0.834	2
3	1	215925	933667	1149593	0.812	1
	2	213257	938931	1152188	0.815	2
4	1	182946	813580	996526	0.816	2
	2	147260	715164	862425	0.829	1
5	1	197564	887309	1084874	0.818	2
	2	180382	759982	940365	0.808	1

TABLE A4.9: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 2

A:	I-Butane	1.3714
B:	N-Butane	1.3929
C:	Neo-Pentane	

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	$\frac{\text{Energy}}{\text{Total}}$	Order
1	1	136539	699756	836296	0.837	1
	2	138556	716791	855348	0.838	2
2	1	111889	568309	680199	0.836	1
	2	150779	768702	919482	0.836	2
3	1	176213	910901	1087115	0.838	1
	2	177322	917463	1094785	0.838	2
4	1	124488	650316	774805	0.839	2
	2	95634	509463	605097	0.842	1
5	1	128920	690810	819730	0.843	2
	2	96090	504285	600375	0.840	1

TABLE A4.10: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 3

A: I-Butane 1.3714
B: N-Butane 3.1073
C: N-Pentane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy / Total	Order
1	1	78640	448656	527296	0.851	1
	2	81633	469803	551436	0.852	2
2	1	95653	496162	591815	0.838	1
	2	112198	602054	714252	0.843	2
3	1	100060	575481	675542	0.850	1
	2	101699	574614	676314	0.850	2
4	1	39561	291019	330580	0.880	2
	2	32735	238594	271330	0.879	1
5	1	34461	293324	327786	0.895	2
	2	23672	195033	218706	0.892	1

TABLE A4.11: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 4

A: N-Pentane 2.9678
B: N-Hexane 2.8736
C: N-Heptane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy / Total	Order
1	1	47566	369847	417413	0.886	1
	2	53879	381639	435518	0.876	2
2	1	44258	276573	320831	0.862	1
	2	67766	388220	455987	0.851	2
3	1	63338	459775	523114	0.879	1
	2	65545	462934	528480	0.876	2
4	1	35091	378774	413865	0.915	2
	2	30335	293612	323948	0.906	1
5	1	35172	426201	461373	0.924	2
	2	28285	289402	317688	0.911	1

TABLE A4.12: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 5

A: Trans-2-Butene 1.0776
B: Cis-2-Butene 8.3300
C: N-Hexane

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy / Total	Order
1	1	637956	1645794	2283751	0.721	2
	2	605238	1626898	2232137	0.729	1
2	1	879358	2168772	3048130	0.712	1
	2	844802	2211227	3056029	0.724	2
3	1	810044	2139255	2949300	0.725	2
	2	799760	2145033	2944793	0.727	1
4	1	217424	668020	885445	0.754	2
	2	187232	585093	772326	0.758	1
5	1	130214	501595	631809	0.794	2
	2	102674	380735	483409	0.788	1

TABLE A4.13: Total Annual Cost (TAC) of Sequences of a Three-component feedstock No. 6

A: Propane 3.5254
B: Trans-2-Butene 1.0776
C: Cis-2-Butene

Feed Type	Sequence Number	Capital Cost	Energy Cost	Total Cost	Energy / Total	Order
1	1	608801	1630589	2239391	0.728	2
	2	451303	1534322	1985626	0.773	1
2	1	192972	560074	753046	0.744	2
	2	143731	491452	635184	0.774	1
3	1	834838	2204405	3039243	0.725	2
	2	766050	2183039	2949089	0.740	1
4	1	788591	2113814	2902405	0.728	2
	2	572320	2266812	2839132	0.775	1
5	1	865390	2333545	3198936	0.729	2
	2	794712	2221418	3016130	0.737	1

TABLE A4.14: Effects of R/R_m on the Total Annual Cost of Sequences of a Four-Component feedstock No. 1

	R/R_m = 1.1				R/R_m = 1.2				R/R_m = 1.3			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	42600	376651	419251	2	42096	389135	431231	2	42575	396917	439492	2
2	43636	360599	404236	1	43129	377444	420574	1	43457	384090	427548	1
3	48738	372087	420825	3	47622	385178	432801	3	47542	387799	435341	3
4	50623	376345	426968	5	49387	388966	438353	4	49155	389841	438997	4
5	46910	378612	425523	4	46050	393843	439893	5	46330	404655	450985	5

TABLE A4.15: Effects of R/R_m on the Total Annual Cost of Sequences of a Four-Component feedstock No. 2

	R/R_m = 1.1				R/R_m = 1.2				R/R_m = 1.3			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	78179	487913	566092	2	78417	515311	593728	2	80744	543742	624487	2
2	78239	480530	558760	1	78616	510918	589534	1	80865	536475	617340	1
3	81948	494375	576323	3	82043	525450	607494	4	84103	552190	636293	4
4	84243	508326	592569	5	84300	540503	624804	5	86280	565753	652033	5
5	80717	496353	577070	4	80727	523707	604434	3	82867	551921	634788	3

TABLE A4.16: Effects of R/R_m on the Total Annual Cost of Sequences of a Four-Component feedstock No. 3

	R/R_m = 1.1				R/R_m = 1.2				R/R_m = 1.3			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	186709	792634	979344	2	188871	851744	1040615	2	196073	896290	1092364	2
2	159976	767339	927315	1	161400	820321	981721	1	167046	871985	1039032	1
3	190231	827741	1017972	5	192106	884500	1076606	5	199022	938464	1137486	5
4	165964	818008	983973	3	167117	873713	1040831	3	172546	924791	1097338	3
5	188102	819787	1007890	4	190117	877478	1067595	4	197160	931472	1128633	4

TABLE A4.17: Effects of Recovery Fraction on the Total Annual Cost of Sequences of a Four-Component feedstock No. 1

	x_R = 0.90				x_R = 0.95				x_R = 0.99			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	34737	267517	302255	1	38043	311559	349603	2	42600	376651	419251	2
2	36539	274586	311126	2	39212	292821	332034	1	43636	360599	404236	1
3	41585	293074	334660	4	44429	319801	364230	4	48738	372087	420825	3
4	43620	292131	335751	5	46542	329534	376076	5	50623	376345	426968	5
5	39209	279667	318876	3	42286	316452	358739	3	46910	378612	425523	4

TABLE A4.18: Effects of Recovery Fraction on the Total Annual Cost of Sequences of a Four-Component feedstock No. 2

	$x_R = 0.90$				$x_R = 0.95$				$x_R = 0.99$			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	63839	400113	463952	2	69707	436357	506064	2	78179	487913	566092	2
2	64525	398605	463130	1	70260	435657	505917	1	78239	480530	558760	1
3	68082	411464	479546	3	73711	445331	519043	3	81948	494375	576323	3
4	70787	429832	500620	5	76219	460331	536551	5	84243	508326	592569	5
5	66706	412019	479726	4	72418	447550	519968	4	80717	496353	577070	4

TABLE A4.19: Effects of Recovery Fraction on the Total Annual Cost of Sequences of a Four-Component feedstock No. 3

	$x_R = 0.90$				$x_R = 0.95$				$x_R = 0.99$			
Seq. No.	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost	Capital Cost	Energy Cost	TAC	Order of Cost
1	146914	680893	827807	2	162701	733889	896590	2	186709	792634	979344	2
2	128061	664617	792678	1	140735	712162	852897	1	159976	767339	927315	1
3	151743	724637	876381	5	166916	769672	936589	5	190231	827741	1017972	5
4	135120	718263	853383	3	147259	763194	910454	3	165964	818008	983973	3
5	149307	711864	861171	4	164695	761355	926050	4	188102	819787	1007890	4

TABLE A4.20: Effects of Feed Vaporisation on the Total Annual Cost of Sequences of a Four-Component feedstock No. 1

	TOTAL ANNUAL COST											
Seq. No.	$q = -0.5$	Order of Cost	$q = 0$	Order of Cost	$q = 0.5$	Order of Cost	$q = 1.0$	Order of Cost	$q = 1.2$	Order of Cost	$q = 1.5$	Order of Cost
1	990972	5	749005	5	543106	5	419251	2	394488	2	370545	1
2	853106	1	638925	2	480144	1	404236	1	388914	1	371367	2
3	896448	3	644220	3	496076	3	420825	3	405243	3	389695	4
4	860416	2	611694	1	480655	2	426968	5	415612	5	403522	5
5	946850	4	707851	4	524678	4	425523	4	406256	4	388762	3

TABLE A4.21: Effects of Feed Vaporisation on the Total Annual Cost of Sequences of a Four-Component feedstock No. 2

	TOTAL ANNUAL COST											
Seq. No.	q =-0.5	Order of Cost	q = 0	Order of Cost	q = 0.5	Order of Cost	q = 1.0	Order of Cost	q = 1.2	Order of Cost	q = 1.5	Order of Cost
1	1035490	5	836767	5	671756	5	566092	2	536513	1	502696	1
2	923479	1	754051	2	627373	1	558760	1	537854	2	516204	2
3	963854	3	770511	3	645313	2	576323	3	556683	4	532651	4
4	939538	2	753772	1	645775	3	592569	5	578409	5	560906	5
5	1000883	4	806835	4	663807	4	577070	4	552432	3	522979	3

TABLE A5.1: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: i-Butane 3.3104*
B: i-Pentane 3.8201
C: n-Hexane 2.8736
D: n-Heptane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	1.8122	1	1.5120	1	424718	2
	2	1.9217	2	1.7272	2	394291	1
	3	2.3892	4	1.9550	4	454841	4
	4	2.6177	5	2.1840	5	461691	5
	5	2.1115	3	1.7287	3	447821	3
2	1	1.6105	1	1.4851	1	212471	1
	2	2.4884	3	2.2182	3	279619	3
	3	2.7936	5	2.2649	4	286485	4
	4	3.7190	4	3.0046	5	366654	5
	5	1.7303	2	1.5712	2	221712	2
3	1	1.8446	1	1.7235	1	359804	2
	2	1.8884	2	1.8184	2	335423	1
	3	3.0272	4	2.5581	4	467300	4
	4	3.1190	5	2.6560	5	463756	3
	5	2.9165	3	2.4593	3	480708	5
4	1	2.1968	2	1.8366	2	514334	3
	2	1.9550	1	1.8354	1	461152	1
	3	2.4276	5	2.0328	5	523283	5
	4	2.2334	3	1.9333	3	479383	2
	5	2.3165	4	2.0300	4	520942	4
5	1	1.5968	5	1.1202	5	494828	5
	2	1.3550	2	1.0222	2	420594	3
	3	1.3079	1	0.9996	1	371468	1
	4	1.3993	3	1.0286	3	374208	2
	5	1.4825	4	1.0774	4	428141	4

* the relative volatilities of pair of adjacent components (i.e α_{AB})

V_B = BDTVL vapour load per mole of feed.

V_U = Underwood vapour load per mole of feed.

TABLE A5.2: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: I-Butane 1.3714
B: n-Butane 3.1073
C: n-Pentane 2.9678
D: n-Hexane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	4.3828	4	3.3114	4	678949	4
	2	3.2824	1	2.8505	1	496198	1
	3	4.2913	3	3.0974	3	624042	3
	4	3.9314	2	3.0720	2	554759	2
	5	4.6420	5	3.5787	5	705091	5
2	1	4.1302	1	3.4998	1	560787	1
	2	4.6032	3	4.3309	3	580141	3
	3	5.0290	4	4.4074	4	589905	4
	4	5.7982	5	5.2464	5	661037	5
	5	4.2339	2	3.5883	2	567644	2
3	1	4.4434	2	3.8394	1	622946	2
	2	4.0032	1	3.9324	2	543733	1
	3	5.3422	4	4.6953	4	688725	4
	4	5.1982	3	4.5954	3	659335	3
	5	5.4825	5	4.7970	5	727934	5
4	1	4.7788	4	2.6582	4	579238	3
	2	2.5616	1	2.4532	1	441214	1
	3	4.7422	3	2.6216	3	588391	5
	4	2.8211	2	2.5243	2	459927	2
	5	4.8825	5	2.7209	5	581479	4
5	1	4.1788	5	1.6646	5	526378	5
	2	1.9615	2	1.5577	2	383184	2
	3	2.0519	3	1.5710	3	388227	3
	4	1.9080	1	1.5419	1	360514	1
	5	3.9693	4	1.6181	4	473207	4

TABLE A5.3: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: Trans-2-butene 1.0776
B: Cis-2-butene 2.8068
C: n-Pentane 2.9678
D: n-Hexane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	15.6614	4	8.5318	1	1947627	4
	2	8.9759	1	8.8147	3	1891789	1
	3	12.7448	3	9.0037	4	1943279	2
	4	9.6032	2	9.3117	5	1944414	3
	5	15.8989	5	8.7562	2	1964624	5
2	1	15.3697	4	12.4916	1	2802761	1
	2	13.6608	1	13.5505	4	2853280	4
	3	15.1385	3	13.3566	3	2852252	3
	4	14.8471	2	14.4242	5	2962222	5
	5	15.4647	5	12.5814	2	2809559	2
3	1	15.7350	4	12.9014	1	2785697	2
	2	13.0608	1	12.9947	2	2755654	1
	3	15.5038	3	13.7707	4	2878494	4
	4	14.2471	2	13.8764	5	2875046	3
	5	16.7654	5	13.6698	3	2890389	5
4	1	16.0704	5	4.8975	2	1128008	3
	2	4.8911	1	4.8147	1	1031916	1
	3	14.9038	3	5.0977	5	1134231	5
	4	5.1420	2	5.0244	4	1050769	2
	5	16.1420	4	4.9951	3	1132966	4
5	1	15.4704	5	3.8614	3	1039334	5
	2	4.2911	2	3.9129	4	931509	3
	3	5.4333	3	3.8363	2	893347	1
	4	4.1767	1	3.9595	5	893801	2
	5	15.2001	4	3.8266	1	988432	4

TABLE A5.4: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: Propane 3.5254
B: Trans-2-butene 1.0776
C: Cis-2-butene 2.8068
D: n-Pentane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	12.1214	3	8.5444	1	1859336	3
	2	15.6975	5	8.6021	2	1648245	1
	3	9.2731	2	9.0809	4	1874356	5
	4	12.9580	4	9.1635	5	1679769	2
	5	8.9798	1	8.8524	3	1860302	4
2	1	5.7099	3	4.2641	1	815718	3
	2	16.2455	5	4.7927	3	698207	1
	3	5.5359	2	5.1310	4	877658	5
	4	16.1150	4	5.6720	5	762070	2
	5	4.4533	1	4.3873	2	816104	4
3	1	14.2151	3	12.7668	1	2807845	2
	2	15.6455	5	12.8398	2	2706091	1
	3	14.0410	2	13.9317	4	2923858	5
	4	15.5150	4	14.0153	5	2837498	3
	5	13.9237	1	13.8343	3	2916864	4
4	1	14.5804	3	13.1441	3	2821345	4
	2	15.7494	5	12.8726	1	2483620	1
	3	13.4410	2	13.3468	5	2823938	5
	4	14.6537	4	13.0861	2	2495390	2
	5	13.3237	1	13.2498	4	2818389	3
5	1	13.9804	4	4.0196	5	1009504	5
	2	15.1494	5	3.9765	4	865025	3
	3	4.0745	1	3.9368	1	847364	2
	4	5.5485	3	3.9699	3	769530	1
	5	4.2186	2	3.9492	2	926381	4

TABLE A5.5: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A:	n-Butane	2.4140
B:	I-Pentane	1.0776
C:	n-Pentane	

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	4.0041	1	3.8864	1	858485	2
	2	5.3335	2	4.0472	2	840322	1
2	1	2.4440	1	2.3826	1	435972	1
	2	6.2302	2	3.3572	2	566571	2
3	1	5.1250	1	5.0975	1	1149570	1
	2	5.5302	2	5.1873	2	1152204	2
4	1	4.4250	2	4.1989	2	995780	2
	2	4.2857	1	3.8193	1	862445	1
5	1	4.6797	2	4.4497	2	1084765	2
	2	4.0357	1	3.9887	1	940373	1

TABLE A5.6: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A:	I-Butane	1.3714
B:	n-Butane	1.3929
C:	neo-Pentane	

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	5.4976	1	4.7721	1	836239	1
	2	5.7445	2	5.0490	2	855321	2
2	1	4.4217	1	4.1479	1	680069	1
	2	7.1653	2	5.7627	2	919420	2
3	1	6.3815	1	6.1982	1	1087091	1
	2	6.4652	2	6.2957	2	1094759	2
4	1	5.6815	2	4.1493	2	774712	2
	2	3.6920	1	3.3624	1	605108	1
5	1	5.8435	2	4.2694	2	819781	2
	2	3.2455	1	3.2115	1	600399	1

TABLE A5.7: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: I-Butane 1.3714
B: n-Butane 3.1073
C: n-Pentane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	3.9715	2	3.0271	1	526815	1
	2	3.4668	1	3.3773	2	551392	2
2	1	3.9962	1	3.6742	1	590819	1
	2	4.8876	2	4.7237	2	714189	2
3	1	4.3316	2	4.6658	2	672508	1
	2	4.1876	1	4.1673	1	676258	2
4	1	3.6316	2	1.4352	2	327578	2
	2	1.4143	1	1.3429	1	271317	1
5	1	3.5885	2	1.2398	2	327258	2
	2	0.9678	1	0.9589	1	218698	1

TABLE A5.8: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: n-Pentane 2.9678
B: n-Hexane 2.8736
C: n-Heptane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	1.6124	1	1.4527	1	415420	1
	2	1.9460	2	1.7423	2	435516	2
2	1	1.5764	1	1.5227	1	317888	1
	2	2.7902	2	2.3999	2	455986	2
3	1	1.9874	1	1.9449	1	523017	1
	2	2.0902	2	2.0425	2	528498	2
4	1	1.2874	2	0.9315	2	408256	2
	2	0.9989	1	0.8775	1	323946	1
5	1	1.2502	2	0.8799	2	460809	2
	2	0.7686	1	0.7555	1	317688	1

TABLE A5.9: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: Trans-2-butene 1.0776
B: Cis-2-butene 8.3300
C: n-Hexane

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	14.9358	2	10.1398	1	2286469	2
	2	10.5468	1	10.4897	2	2232583	1
2	1	15.1053	2	13.6893	1	3051528	1
	2	14.6078	1	14.5970	2	3056641	2
3	1	15.2103	2	13.8051	1	2950060	2
	2	13.9078	1	13.9064	2	2935362	1
4	1	14.5103	2	3.2266	1	889870	2
	2	.3.2351	1	3.2792	2	772461	1
5	1	14.4338	2	1.9303	2	637171	2
	2	1.8293	1	1.8283	1	483478	1

TABLE A5.10: List of BDTVL vapour load, Underwood vapour load and the Total Annual Cost (TAC) of sequences.

A: Propane 3.5254
B: Trans-2-butene 1.0776
C: Cis-2-butene

Feed Type	Seq. No.	V_B	Order	V_U	Order	TAC	Order
1	1	10.5930	1	10.5719	1	2239437	2
	2	15.4527	2	10.6735	2	1986010	1
2	1	4.1706	1	4.1535	1	752189	2
	2	16.2673	2	4.7904	2	635278	1
3	1	14.0933	1	14.0886	1	3039827	2
	2	15.5673	2	14.1741	2	2949666	1
4	1	13.3933	1	13.3554	2	2902554	2
	2	14.5624	2	13.0532	1	2539652	1
5	1	14.5791	2	14.5407	2	3199491	2
	2	14.3432	1	14.1922	1	3016782	1

TABLE A6.1: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
$(\alpha_{AB} = 2.1 \; ; \; \alpha_{BC} = 2.1)$

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	379119	0.839	2.2727	1.6313	1.6361
	2	318018		1.6091	1.4297	1.4599
0.01,0.80,0.10	1	588411	1.015	2.9727	2.8962	2.8988
	2	597232		3.0727	2.9932	2.9888
0.80,0.10,0.10	1	347926	1.377	2.2091	2.1057	2.0427
	2	479119		3.7727	3.1196	3.1445
0.10,0.30,0.60	1	444508	0.894	2.4727	2.0027	2.0293
	2	397343		2.0273	1.8974	1.8958
0.10,0.60,0.30	1	533361	0.973	2.7727	2.5416	2.5510
	2	518775		2.6545	2.5608	2.5510
0.10,0.70,0.20	1	561869	0.994	2.8727	2.7192	2.7249
	2	558295		2.8636	2.7776	2.7698
0.20,0.10,0.70	1	362758	0.905	2.2636	1.6587	1.6942
	2	328386		1.9182	1.5864	1.6546
0.20,0.30,0.50	1	430699	0.975	2.4636	2.0512	2.0941
	2	420126		2.3364	2.0988	2.1028
0.20,0.40,0.40	1	461815	0.996	2.5636	2.2381	2.2680
	2	460028		2.5455	2.3348	2.3278
0.20,0.50,0.30	1	494326	1.013	2.6636	2.4219	2.4419
	2	500765		2.7545	2.5647	2.5534

V_B = Vapour load per mole of feed by the BDTVL equation.
V_U = Vapour load per mole of feed by the Underwood equation.
V_M = Vapour load per mole of feed by the Malone et al(1985) equation.
I/D = Fraction of the TAC of INDIRECT to DIRECT sequences.

TABLE A6.1: (Continued)

0.20,0.60,0.20	1	522357	1.038	2.7636	2.6037	2.6158
	2	542144		2.9636	2.7905	2.7796
0.30,0.20,0.50	1	388749	1.022	2.3545	1.9134	1.9850
	2	397359		2.4364	2.0641	2.1013
0.30,0.40,0.30	1	455938	1.063	2.5545	2.3009	2.3328
	2	484859		2.8545	2.5657	2.5611
0.40,0.10,0.50	1	354304	0.981	2.2545	1.7033	1.7523
	2	347710		2.2273	1.7791	1.8730
0.05,0.65,0.30	1	554339	0.956	2.8273	2.6010	2.6056
	2	530103		2.6045	2.5579	2.5520

TABLE A6.2: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture. ($\alpha_{AB} = 1.50$; $\alpha_{BC} = 1.316$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10.0.80	1	1113681	0.821	6.0177	4.9913	4.9501
	2	914392		4.5775	4.1292	4.0586
0.10,0.80,0.10	1	1411241	1.008	6.7177	6.5942	6.6009
	2	1423175		6.9575	6.6870	6.6659
0.80,0.10,0.10	1	721383	1.358	4.0595	3.8464	3.7351
	2	979696		7.6575	5.4057	5.4759
0.20,0.10,0.70	1	1039878	0.848	5.7380	4.7471	4.7765
	2	881428		5.0175	4.1436	4.1010
0.20,0.40,0.40	1	1176464	0.962	6.0380	5.4995	5.5708
	2	1131439		6.0375	5.3760	5.2811
0.20,0.30,0.50	1	1132506	0.930	5.9380	5.2562	5.3540
	2	1053374		5.6975	4.9808	4.8858
0.20,0.60,0.20	1	1264567	1.015	6.2380	5.9739	6.0044
	2	1283425		6.7175	6.1409	6.0781
0.10,0.70,0.20	1	1369608	0.987	6.6177	6.3699	6.3841
	2	1351758		6.6175	6.3314	6.2915
0.15,0.60,0.35	1	1294530	0.989	6.3778	6.0574	6.2091
	2	1280226		6.4975	6.0534	6.0632
0.30,0.30,0.40	1	1071430	0.982	5.6582	5.0714	5.1910
	2	1051692		6.1375	5.1188	5.0434
0.30,0.40,0.30	1	1117715	1.016	5.7582	5.3269	5.4078
	2	1135959		6.4775	5.5392	5.4578
0.35,0.20,0.45	1	993257	0.968	5.4184	4.7135	4.8928
	2	961901		6.0175	4.7462	4.7250

TABLE A6.2: (Continued)

0.40,0.15,0.45	1	937719	0.972	5.2282	4.4792	4.5857
	2	911503		6.0675	4.5755	4.6186
0.50,0.05,0.45	1	816779	0.962	4.8487	3.9625	4.0107
	2	785979		6.1675	4.1338	4.4229
0.50,0.10,0.40	1	852563	1.011	4.8987	4.1549	4.2558
	2	862119		6.3375	4.4786	4.6356
0.05,0.65,0.30	1	1387113	0.952	6.7076	6.3463	6.3572
	2	1320933		6.2275	6.0765	6.0450
0.40,0.30,0.30	1	1015425	1.046	5.3785	4.9079	5.0281
	2	1061761		6.5775	5.3010	5.2544

TABLE A6.3: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
($\alpha_{AB} = 3.0$; $\alpha_{BC} = 2.5$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	291554	0.908	1.5200	1.1600	1.1634
	2	264746		1.2200	1.0662	1.1038
0.10,0.80,0.10	1	463314	1.009	2.2200	2.1770	2.1785
	2	467947		2.3400	2.2737	2.2712
0.80,0.10,0.10	1	245055	1.563	1.6600	1.6029	1.5677
	2	382971		3.0400	2.4960	2.5249
0.10,0.40,0.50	1	372896	0.932	1.8200	1.6018	1.6123
	2	347240		1.7000	1.6033	1.6033
0.10,0.60,0.30	1	418321	0.977	2.0200	1.8903	1.8954
	2	408679		2.0200	1.9415	1.9370
0.20,0.10,0.70	1	272471	0.999	1.5400	1.2014	1.2211
	2	272110		1.4800	1.1975	1.2735
0.15,0.10,0.75	1	281828	0.945	1.5300	1.1796	1.1922
	2	266360		1.3500	1.1281	1.1861
0.15,0.20,0.65	1	316595	0.938	1.6300	1.3328	1.3600
	2	297006		1.5100	1.3271	1.3548
0.20,0.20,0.60	1	306841	0.998	1.6400	1.3580	1.3908
	2	306120		1.6400	1.4078	1.4444
0.15,0.40,0.45	1	364455	0.986	1.8300	1.6291	1.6431
	2	359213		1.8300	1.6912	1.6929
0.08,0.70,0.22	1	444891	0.981	2.1160	2.0216	2.0246
	2	436331		2.1280	2.0696	2.0658
0.05,0.85,0.10	1	479762	0.998	2.260	2.2178	2.2185
	2	487573		2.2900	2.2569	2.2554
0.05,0.40,0.55	1	379524	0.896	1.8100	1.5756	1.5815
	2	339867		1.5700	1.5195	1.5186

TABLE A6.3 (Continued)

0.30,0.10,0.60	1	266255	1.084	1.5600	1.2526	1.2789
	2	288526		1.7400	1.3614	1.4615
0.25,0.40,0.35	1	358298	1.052	1.8500	1.6875	1.7046
	2	376759		2.0900	1.8790	1.8842
0.20,0.30,0.50	1	333501	1.016	1.7400	1.5092	1.5323
	2	338980		1.8000	1.6000	1.6154
0.20,0.60,0.20	1	410624	1.040	2.0400	1.9504	1.9569
	2	427097		2.2800	2.1353	2.1309

TABLE A6.4: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture. (α_{AB} = 2.667; α_{BC} = 1.500)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	652828	0.853	3.0800	2.7983	2.7818
	2	556851		2.8440	2.5155	2.4810
0.10,0.80,0.10	1	807713	1.005	3.7800	3.7460	3.7480
	2	811355		4.0480	3.8381	3.8262
0.80,0.10,0.10	1	348514	1.375	2.1000	2.0377	2.0055
	2	479325		4.7480	2.9964	3.0888
0.20,0.10,0.70	1	600391	0.868	2.9400	2.6672	2.6709
	2	521418		3.1160	2.4720	2.4704
0.20,0.30,0.50	1	649065	0.936	3.1400	2.9517	2.9800
	2	607320		3.4600	2.9183	2.8782
0.20,0.60,0.20	1	719209	1.009	3.4400	3.3670	3.3760
	2	726029		3.9760	3.5309	3.4991
0.30,0.10,0.60	1	553522	0.888	2.8000	2.5403	2.5600
	2	491414		3.3880	2.4495	2.5134
0.30,0.40,0.30	1	631662	1.006	3.1000	2.9800	3.0040
	2	635828		3.9040	3.1840	3.1554
0.40,0.10,0.50	1	511072	0.917	2.6600	2.4200	2.4491
	2	468728		3.6600	2.4600	2.5934
0.40,0.20,0.40	1	536929	0.988	2.7600	2.5778	2.6320
	2	530282		3.8320	2.7610	2.8113
0.40,0.30,0.30	1	565104	1.030	2.8600	2.7281	2.7640
	2	581081		4.0040	3.0246	3.0326
0.35,0.30,0.35	1	585066	1.000	2.9300	2.7817	2.8180
	2	585318		3.8680	2.9864	2.9825
0.50,0.10,0.40	1	466119	0.980	2.5200	2.3092	2.3382
	2	456887		3.9320	2.5181	2.6987

TABLE A6.4 (Continued)

0.55,0.05,0.40	1	427641	0.965	2.400	2.1662	2.1734
	2	412774		3.9820	2.3531	2.6476
0.50,0.20,0.30	1	497474	1.053	2.6200	2.4725	2.5240
	2	523601		4.1040	2.8463	2.9214
0.15,0.30,0.55	1	673106	0.919	3.2100	3.0111	3.0340
	2	618491		3.3240	2.9095	2.8640
0.60,0.10,0.30	1	423211	1.081	2.3800	2.2096	2.2273
	2	457345		4.2040	2.6319	2.8210
0.60,0.20,0.10	1	455817	1.145	2.4800	2.3751	2.4160
	2	521909		4.3760	2.9713	3.0475
0.20,0.70,0.10	1	740841	1.028	3.5400	3.5038	3.5080
	2	762212		4.1480	3.7268	3.7088
0.05,0.50,0.45	1	765990	0.930	3.5500	3.4008	3.4060
	2	712551		3.3960	3.2699	3.2454

TABLE A6.5: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
($\alpha_{AB} = 3.53$; $\alpha_{BC} = 1.08$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	3899776	0.891	14.1743	14.1320	14.0966
	2	3476058		15.3949	13.7949	12.9344
0.10,0.80,0.10	1	4049223	0.999	14.8743	14.8691	14.8695
	2	4043849		16.4269	14.9533	14.8355
0.80,0.15,0.05	1	105279	1.016	4.4243	4.4154	4.3924
	2	1069788		17.2006	5.5181	5.4134
0.20,0.40,0.40	1	3552471	0.938	13.0743	13.0508	13.0553
	2	3333487		16.0846	13.0180	12.2747
0.20,0.70,0.10	1	3619650	0.979	13.3743	13.3685	13.3695
	2	3543941		16.5269	13.5760	13.3752
0.10,0.50,0.40	1	3982920	0.971	14.5743	14.5533	14.5553
	2	3865609		15.9846	14.4596	14.0064
0.30,0.50,0.20	1	3167678	0.950	11.7743	11.7611	11.7648
	2	3010816		16.4794	11.9824	11.5059
0.50,0.40,0.10	1	2334212	0.950	8.8743	8.8655	8.8695
	2	2218250		16.8269	9.4026	9.1729
0.70,0.20,0.10	1	1472149	0.951	5.8743	5.8608	5.8695
	2	1399916		17.0269	6.5258	6.5116
0.05,0.08,0.87	1	4110387	0.908	14.8543	14.8107	14.7648
	2	3733645		15.2417	14.4392	13.9181
0.10,0.30,0.60	1	3939507	0.943	14.3743	14.3427	14.3457
	2	3714436		15.6897	14.1283	13.4658
0.60,0.20,0.20	1879645		0.950	7.2743	7.2524	7.2648
	2	1793822		16.7794	7.6113	7.3652

TABLE A6.5 (Continued)

0.50,0.30,0.20	1	2306532	0.922	8.7743	8.7564	8.7648
	2	2125786		16.6794	9.1072	8.6916
0.45,0.40,0.15	1	2535801	0.942	9.5743	9.5621	9.5672
	2	2388751		16.7032	9.9717	9.6414
0.20,0.50,0.30	1	3575171	0.953	13.1743	13.1567	13.1600
	2	3408343		16.2320	13.2052	12.6333
0.20,0.30,0.50	1	3526343	0.921	12.9743	12.9448	12.9505
	2	3247905		15.9372	12.8294	11.9238

TABLE A6.6: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
($\alpha_{AB} = 4.00$; $\alpha_{BC} = 1.15$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	1944307	0.882	7.800	7.7408	7.7152
	2	1714304		8.3800	7.4803	7.0775
0.10,0.80,0.10	1	2088040	0.991	8.5000	8.4927	8.4933
	2	2068774		9.3600	8.5791	8.5217
0.80,0.10,0.10	1	593328	1.037	2.9000	2.8773	2.8576
	2	615302		10.0600	3.5569	3.7884
0.10,0.30,0.60	1	1984458	0.925	8.0000	7.9559	7.9600
	2	1835777		8.6600	7.7982	7.4839
0.10,0.50,0.40	1	2023583	0.956	8.2000	8.1707	8.1733
	2	1933681		8.9400	8.1127	7.8951
0.10,0.70,0.20	1	2063383	0.981	8.4000	8.3854	8.3867
	2	2023166		9.2200	8.4243	8.3115
0.40,0.40,0.20	1	1425768	0.953	6.0000	5.9794	5.9867
	2	1358610		9.5200	6.2872	6.0879
0.20,0.40,0.40	1	1806380	0.934	7.4000	7.3674	7.3733
	2	1688018		9.0400	7.3707	7.0277
0.20,0.70,0.10	1	1866877	0.982	7.7000	7.6920	7.6933
	2	1833735		9.4600	7.8952	7.7999
0.40,0.50,0.10	1	1446170	0.981	6.1000	6.0899	6.0933
	2	1418712		9.6600	6.5136	6.4036
0.30,0.50,0.20	1	1633717	0.961	6.8000	6.7819	6.1067
	2	1570139		9.4200	7.0112	6.7974
0.40,0.20,0.40	1	1378782	0.891	5.8000	5.7575	5.7733
	2	1227831		9.2400	5.8085	5.4929
0.50,0.30,0.20	1	1211584	0.948	5.2000	5.1761	5.1867
	2	1148106		9.6200	5.5426	5.4079

TABLE A6.6: (Continued)

0.50,0.40,0.10	1	1232788	0.987	5.3000	5.2883	5.2933
	2	1217139		9.7600	5.8114	5.7283
0.60,0.20,0.20	1	996603	0.943	4.4000	4.3711	4.3867
	2	940160		9.7200	4.7615	4.7557
0.70,0.10,0.20	1	780351	0.915	3.6000	3.5626	3.5515
	2	713892		9.8200	3.8998	4.1299
0.70,0.20,0.10	1	809689	1.011	3.7000	3.6829	3.6933
	2	818548		9.9600	4.3542	4.4211
0.05,0.70,0.25	1	2162894	0.985	8.7500	8.7326	8.7333
	2	2130901		9.1000	8.6992	8.6226
0.07,0.10,0.83	1	2007596	0.890	8.0100	7.9506	7.9233
	2	1786667		8.3080	7.6777	7.3615
0.60,0.30,0.10	1	1018792	1.000	4.5000	4.4862	4.4933
	2	1017566		9.8600	5.0953	5.0675

TABLE A6.7: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
(α_{AB} = 2.667; α_{BC} = 3.727)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	219248	0.996	1.3161	0.8172	0.8246
	2	218419		0.8840	0.7845	0.8231
0.10,0.80,0.10	1	409489	1.022	2.0161	1.9563	1.9575
	2	418352		2.0881	2.0547	2.0534
0.80,0.10,0.10	1	251657	1.517	1.7080	1.6379	1.5893
	2	381787		2.7881	2.5170	2.5290
0.10,0.20,0.70	1	258021	0.940	1.4161	0.9861	1.0060
	2	242546		1.0561	0.9802	0.9987
0.10,0.40,0.50	1	311988	0.971	1.6161	1.3134	1.3232
	2	303070		1.4001	1.3473	1.3500
0.10,0.50,0.40	1	336790	0.987	1.7161	1.4750	1.4818
	2	332308		1.5721	1.5261	1.5257
0.10,0.60,0.30	1	360670	0.999	1.8161	1.6359	1.6403
	2	360216		1.7441	1.7033	1.7016
0.15,0.10,0.75	1	214708	1.084	1.3441	0.8646	0.8792
	2	232838		1.0201	0.8828	0.9343
0.15,0.30,0.55	1	284745	1.003	1.5441	1.2039	1.2219
	2	285619		1.3641	1.2771	1.2881
0.15,0.50,0.35	1	341286	1.019	1.7441	1.5306	1.5390
	2	347707		1.7081	1.6429	1.6425
0.20,0.10,0.70	1	210816	1.170	1.3721	0.9155	0.9338
	2	246598	1.1561		0.9889	1.0484
0.20,0.40,0.40	1	316184	1.040	1.6721	1.4236	1.4378
	2	328868		1.6721	1.5787	1.5828

TABLE A6.7: (Continued)

0.05,0.70,0.75	1	391712	0.969	1.8881	1.7399	1.7416
	2	379506		1.7801	1.7608	1.7595
0.20,0.60,0.20	1	366298	1.069	1.8721	1.7494	1.7549
	2	391519		2.0161	1.9424	1.9403
0.25,0.40,0.35	1	312709	1.104	1.7001	1.4803	1.4950
	2	345211		1.8081	1.6980	1.7024
0.40,0.10,0.50	1	220670	1.340	1.4841	1.1428	1.1523
	2	297738		1.7001	1.4675	1.5248
0.30,0.10,0.60	1	212601	1.295	1.4281	1.0255	1.0431
	2	275350		1.4281	1.2200	1.2832
0.30,0.50,0.20	1	343952	1.128	1.8281	1.7024	1.7109
	2	387887		2.1161	2.0049	2.0046

TABLE A6.8: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
(α_{AB} = 1.143; α_{BC} = 3.50)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.10,0.10,0.80	1	582890	0.950	9.0295	2.4908	2.4502
	2	553887		2.4595	2.4233	2.4170
0.10,0.80,0.10	1	1981346	1.003	9.7295	8.9255	8.9320
	2	1987054		9.0377	9.0288	9.0273
0.80,0.10,0.10	1	1850419	1.077	9.3535	8.5584	7.9051
	2	1992351		9.7377	9.6666	9.6452
0.10,0.30,0.60	1	1000743	0.959	9.2295	4.3762	4.4320
	2	959263		4.3390	4.3200	4.3053
0.10,0.50,0.40	1	1401914	0.976	9.4295	6.2055	6.2320
	2	1368068		6.2185	6.2055	6.1938
0.05,0.80,0.15	1	1928579	0.993	9.7035	8.5006	8.5060
	2	1915749		8.5179	8.5136	8.5125
0.05,0.40,0.55	1	1128661	0.948	9.3035	4.8826	4.9060
	2	1070030		4.7589	4.7504	4.7433
0.15,0.10,0.75	1	666194	0.987	9.0555	2.8918	2.8398
	2	657731		2.9794	2.9342	2.9207
0.15,0.30,0.55	1	1082598	0.980	9.2555	4.7887	4.8580
	2	1060525		4.8589	4.8332	4.8123
0.15,0.50,0.35	1	1476547	0.992	9.4555	6.6259	6.6580
	2	1465408		6.7384	6.7203	6.7047
0.20,0.70,0.10	1	1942058	1.012	9.6815	8.8732	8.8840
	2	1965394		9.1377	9.1200	9.1149
0.40,0.30,0.30	1	1515718	1.036	9.3855	6.9197	6.9880
	2	1569539		7.4582	7.4129	7.3800

TABLE A6.8: (Continued)

0.30,0.10,0.60	1	934931	1.033	9.1335	4.1608	4.0087
	2	966121		4.5390	4.4801	4.4464
0.05,0.10,0.85	1	508259	0.889	9.0035	2.1143	2.0605
	2	451941		1.9396	1.9173	1.9166
0.20,0.10,0.70	1	752933	1.006	9.0815	3.3071	3.2295
	2	757435		3.4992	3.4480	3.4270
0.30,0.20,0.50	1	1142713	1.021	9.2335	5.1195	5.2360
	2	1166442		5.4787	5.4317	5.3965
0.20,0.30,0.50	1	1167327	0.992	9.2815	5.2073	5.2840
	2	1158555		5.3787	5.3477	5.3218

TABLE A6.9 : List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture. ($\alpha_{AB} = 1.15$; $\alpha_{BC} = 4.00$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.05,0.10,0.85	1	478064	0.889	8.5300	1.9351	1.8785
	2	424819		1.8000	1.7810	1.7805
0.10,0.80,0.10	1	1874812	1.003	9.2600	8.4897	8.4933
	2	1880524		8.6000	8.5926	8.5894
0.80,0.10,0.10	1	1754807	1.077	8.9800	8.1839	7.5558
	2	1889840		9.3000	9.2408	9.2210
0.10,0.30,0.60	1	938910	0.963	8.7600	4.1138	4.1600
	2	904590		4.1000	4.0841	4.0711
0.10,0.50,0.40	1	1320678	0.981	8.9600	5.8724	5.8933
	2	1296139		5.9000	5.8891	5.8782
0.10,0.70,0.20	1	1691202	0.996	9.1600	7.6187	7.6267
	2	1685258		7.7000	7.6917	7.6856
0.30,0.20,0.50	1	1078418	1.022	8.7800	4.8501	4.9467
	2	1102365		5.2000	5.1607	5.1304
0.20,0.10,0.70	1	710246	1.014	8.6200	3.1054	3.0139
	2	720471		3.3000	3.2571	3.2392
0.20,0.40,0.40	1	1287016	1.001	8.9200	5.8110	5.8533
	2	1288516		6.0000	5.9782	5.9580
0.20,0.70,0.10	1	1834225	1.014	9.2200	8.4462	8.4533
	2	1860026		8.7000	8.6852	8.6791
0.40,0.50,0.10	1	1794851	1.034	9.1400	8.3589	8.3733
	2	1856393		8.9000	8.8704	8.8590
0.05,0.70,0.25	1	1637550	0.986	9.1300	7.2080	7.2133
	2	1614409		7.2000	7.1956	7.1918
0.30,0.10,0.60	1	883533	1.034	8.6800	3.9342	3.7709
	2	913898		4.3000	4.2504	4.2220
0.40,0.10,0.50	1	1058650	1.051	8.7400	4.7757	4.5279
	2	1112618		5.3000	5.2471	5.2111

TABLE A6.10: List of feed compositions, Total Annual Cost (TAC) and Vapour loads for direct and indirect sequences of a three-component mixture.
($\alpha_{AB} = 1.08$; $\alpha_{BC} = 8.33$)

Feed Composition	Seq. No.	TAC	I/D	V_B	V_U	V_M
0.07,0.10,0.83	1	838633	0.952	15.3223	2.9473	2.7539
	2	798702		2.9537	2.9483	2.9438
0.10,0.80,0.10	1	3645152	1.000	16.0473	14.5606	14.5623
	2	3643251		14.6637	14.6621	14.6607
0.80,0.10,0.10	1	3576034	1.016	15.9327	14.4344	13.2191
	2	3631529		15.3637	15.3616	15.3415
0.10,0.30,0.60	1	1732350	0.970	15.5473	6.6153	6.6374
	2	1680437		6.6637	6.6603	6.6532
0.10,0.50,0.40	1	2501103	0.985	15.7473	9.7975	9.8074
	2	2464169		9.8637	9.8614	9.8561
0.10,0.70,0.20	1	3268719	0.995	15.9473	12.9736	12.9774
	2	3253929		13.0637	13.0619	13.0592
0.20,0.10,0.70	1	1329304	0.979	15.4310	4.9668	4.6174
	2	1301865		5.1637	5.1547	5.1412
0.20,0.30,0.50	1	2092972	0.989	15.6310	8.1763	8.2060
	2	2067264		8.3637	8.3583	8.3463
0.20,0.70,0.10	1	3589913	1.003	16.0310	14.5426	14.5460
	2	3601748		14.7637	14.7607	14.7578
0.30,0.10,0.60	1	1710100	0.993	15.5146	6.5375	6.0510
	2	1697731		6.8637	6.8637	6.8353
0.40,0.30,0.30	1	2826569	1.004	15.7982	11.3177	11.3432
	2	2840994		11.7637	11.7559	11.7413
0.05,0.70,0.25	1	3128831	0.990	15.9055	12.1906	12.1930
	2	3098609		12.2137	12.2128	12.2110

TABLE A6.10: (Continued)

0.20,0.50,0.30	1	2849541	0.993	15.8310	11.3632	11.3760
	2	2826995		11.5637	11.5598	11.5519
0.30,0.50,0.20	1	3198805	1.004	15.9146	12.9334	12.9446
	2	3212760		13.2637	13.2586	13.2506
0.10,0.05,0.85	1	734556	0.985	15.2973	2.5918	2.2786
	2	723434		2.6637	2.6548	2.6496
0.40,0.10,0.50	1	2098719	0.992	15.5983	8.1135	7.4846
	2	2081611		8.5637	8.5528	8.5319
0.13,0.10,0.77	1	1065276	0.962	15.3724	3.8739	3.6138
	2	1024571		3.9737	3.9661	3.9572
0.05,0.10,0.85	1	766659	0.940	15.3055	2.6424	2.4669
	2	720608		2.6137	2.6093	2.6064
0.83,0.10,0.07	1	3675320	1.020	15.9578	14.9090	13.6492
	2	3749545		15.8737	15.8615	15.8540

APPENDIX B

SHORTCUT DESIGN STEPS

B-1 Component Distribution between the top and bottom Products

This is estimated using the Hengstebeck(1961)-Geddes(1958) equation given in the form of

$$\mathrm{Log}(d_i/b_i) = A + B\ \mathrm{Log}\ \alpha_i \qquad \ldots\ldots\ldots(B1-1)$$

where A and B are the correlation constants.

Analytically, two approaches have been put forward in solving Equation B1-1. These are given by Yaws et al(1979) and Chang(1980). Both approaches are described below.

(a) Yaws et al(1979)

A material balance for the i-component in the feed, F

$$f_i = d_i + b_i \qquad \ldots\ldots\ldots(B1-2)$$

where f_i is the moles of component i in the feed

The quantity of component i in the distillate can be expressed as a mole fraction recovered of d_i/f_i. Likewise, b_i/f_i

or $(1-d_i/f_i)$ is the mole fraction of component i recovered in the bottoms.

Substituting in (B1-2) gives

$$\log\left[\frac{d_i f_i}{(1-d_i/f_i)}\right] = A + B \operatorname{Log} \alpha_i \qquad ....(B1\text{-}3)$$

Rearranging Equation B1-3 becomes

$$d_i/f_i = 10^A\ \alpha_i^{\,B}/(1 + 10^A\ \alpha_i^{\,B}) \qquad ....(B1\text{-}4)$$

By material balance, the recovery fraction of component i in the bottom is

$$b_i/f_i = 1/(1 + 10^A\ \alpha_i^{\,B}) \qquad ....(B1\text{-}5)$$

The correlation constants A and B are obtained by specifying a desired recovery of the light key component, LK, in the distillate and the recovery of the heavy key, HK, in the bottoms.

Then,

$$A = -\operatorname{Log}\left[\frac{(b_{HK}/f_{HK})}{(1-(b_{HK}/f_{HK}))}\right] \qquad ....(B1\text{-}6)$$

$$B = \{\operatorname{Log}[((d_{LK}/f_{LK})/(1-(d_{LK}/f_{LK}))][((b_{HK}/f_{HK})/(1-(b_{HK}/f_{HK}))]\} \;/\{\operatorname{Log} \alpha_{LK}\}$$

or

$$B = \frac{\operatorname{Log}\left\{\left[\frac{d_{LK}/f_{LK}}{1-(d_{LK}/f_{LK})}\right]\left[\frac{b_{HK}/f_{HK}}{1-(b_{HK}/f_{HK}}\right]\right\}}{\operatorname{Log} \alpha_{LK}} \qquad ...(B1\text{-}7)$$

(b) Chang(1980)

He established the number of moles of the keys by the following relations:

$d_{LK} = (d_{LK}/f_{LK})(f_{LK})$ ....(B1-8)

$b_{LK} = f_{LK} - d_{LK}$ ....(B1-9)

$d_{HK} = (1 - (b_{HK}/f_{HK}))(f_{HK})$ ......(B1-10)

$b_{HK} = f_{HK} - d_{HK}$ ....(B1-11)

Substituting the ith component in Equation (B1-1) for LK and HK, two equations are obtained in two unknowns A and B which can be solved simultaneously.

$A = \mathrm{Ln}(d_{HK}/b_{HK})$ ....(B1-12)

$B = \mathrm{Ln}[(d_{LK}/b_{LK})(b_{HK}/d_{HK})]/\mathrm{Ln}\ \alpha_{LK}$ ....(B1-13)

Eliminating d_i between Equation (B1-1) and (B1-2), equations similar to B1-4 and B1-5 in the form

$$b_i = \frac{f_i}{1 + \exp(A + B\ \mathrm{Ln}\ \alpha_i)} \quad \text{.....(B1-14)}$$

$$d_i = f_i - b_i \quad \text{.....(B1-15)}$$

are obtained

But $x_{Di} = d_i/\ \ d_i$ ....(B1-16) and $x_{Bi} = b_i / \ b_i$ ....(B1-17)

If $s_1 = d_{LK}/f_{LK}$ and $s_2 = b_{HK}/f_{HK}$, two functions g_1 and g_2 given by

$$g_1(s_1,s_2) = (x_{D,HK})_{ca} - x_{D,HK} \qquad \text{........(B1-18)}$$

$$g_2(s_1,s_2) = (x_{B,LK})_{ca} - x_{B,LK} \qquad \text{........(B1-19)}$$

are obtained, where $(x_{D,HK})_{ca}$ and $(x_{B,LK})_{ca}$ are the moles fractions of the key components calculated by equations B1-16 and B1-17 based on assumed values of s_1 and s_2 while $x_{D,HK}$ and $x_{B,HK}$ are the specified mole fractions at distillate and bottom respectively.

The last two equations are solved by the Newton-Raphson method.

It is noted that the approach of Yaws et al(1979) handles cases where recovery fractions of the LK component in the light fraction and HK component in the heavy fractions are specifield. The Chang(1980) approach on the other hand, handles cases where the product purity is specified in terms of the mole fraction of HK component in the light product and LK component in the heavy product. In this case a trial-and-error calculation would be required.

Each of these approaches are incorporated in the package.

B-2 Minimum Reflux Ratio, R_m

The minimum reflux ratio, R_m, is obtained by the Underwood(1948) method. The equations can be stated in the form

$$1 - q = \sum_{i}^{m} \frac{\alpha_i x_{Fi}}{\alpha_i - \theta} \qquad \text{........(B2-1)}$$

$$R_m + 1 = \sum_{i}^{m} \frac{\alpha_i x_{Di}}{\alpha_i - \theta} \qquad \text{.........(B2-2)}$$

θ is the root of the equation whose value must lie between values of the relative volatility of the light and heavy keys. x is the liquid mole fraction of feed (F) or of distillate (D). This is usually found by a trial-and-error calculations. However, in this work, the Bisection (or Half-Interval) method which is considered to always converge to the desired solution is employed. The algorithm for the method is available in many numerical textbooks (James et al(1977), Carnahan et al(1969))

B-3 Minimum number of theoretical plates, N_m

This is based on the Fenske(1932) equation od the form

$$N_m = \mathrm{Ln}[(x_{D,LK}/x_{B,LK})(x_{B,HK}/x_{D,HK})]/\mathrm{Ln}\ \alpha_{LK} \quad \ldots.(B3-1)$$

Normally, the reboiler is considered as one theoretical plate and also a partial condenser, if one is used, is considered as one theoretical plate.

B-4 Feed-point Location

The empirical equation given by Kirkbride(1944) is used. This is given by

$$\mathrm{Log}\left[\frac{N_r}{N_s}\right] = 0.206\mathrm{Log}\left[\left\{\frac{B}{D}\right\}\left\{\frac{x_{F,HK}}{x_{F,LK}}\right\}\left\{\frac{x_{B,LK}}{x_{D,HK}}\right\}^2\right] \quad \ldots\ldots(B4-1)$$

[N_r and N_s are the number of plates above and below the feed respectively.]

B-5 Theoretical number of plates, N

This is obtained by the Erbar-Maddox(1961) graphical correlation. The correlation gave a simpler and more accurate graphical correlation of Gilliland plot. We fitted the graphical correllation into an equation of the form

$$\mathrm{Ln}(N-N_m) = -0.37866\ \mathrm{Ln}\left[\frac{(R-R_m)}{N_m^{1.25}\ R_m^{0.96}}\right] + 0.796 \qquad \ldots.(B5-1)$$

B-6 Vapour Density, ρ_V

The vapour density, ρ_V, in Kg/m^3 is obtained at the top and bottom column temperature using the following expressions [King(1980)]

$$\rho_{V,D} = \left[\frac{1}{22.4}\ \frac{273.0}{T_D + 273.0}\ \frac{P_D}{P_1}\right] \sum_i^m x_{Di}(MW)_i \qquad \ldots\ldots(B6-1)$$

$$\rho_{V,B} = \left[\frac{1}{22.4}\ \frac{273.0}{T_B + 273.0}\ \frac{P_B}{P_1}\right] \sum_i^m x_{Bi}(MW)_i \qquad \ldots\ldots(B6-2)$$

(m = 1,2,3 ...no. of components)

P_D,P_B are the operating pressures (atm) at the top and bottom products. T_D and T_B are the temperatures at the top and bottom product respectively. P_1 is the standard atmospheric pressure and MW is the molecular weight of the component.

B-7 Superficial Velocity, u, and Column Diameter, D_C

Fair(1961)'s graphical correlation is used. The correlation uses the Souder-Brown(1934)'s equation of the form

$$u = k_V((\rho_L - \rho_V)/\rho_V)^{0.5} \quad ....(B7\text{-}1)$$

where

u = maximum allowable vapour velocity based on the gross (total) column cross-section, m/s

k_V= capacity factor

The values of the capacity constant are obtained from the Fair's graph (reproduced in Figure B7-1) which shows the capacity constant correlated against the Flow Parameter, $[\, L/V(\rho_V/\rho_L)^{0.5}]$. In the design of the columns and in the programs, a curve for the tray spacing of 24 ins (61 cms) is fitted numerically using linear interpolation technique.

Another useful correlation of the superficial velocity is that given by Lowenstein(1961)

$$u = (-0.171 l_t^2 + 0.27 l_t - 0.047)[(\rho_L - \rho_V)/\rho_V)]^{0.5} \quad ..(B7\text{-}2)$$

where l_t is the plate spacing in meters.

The column diameter, D_C, can then be calculated as

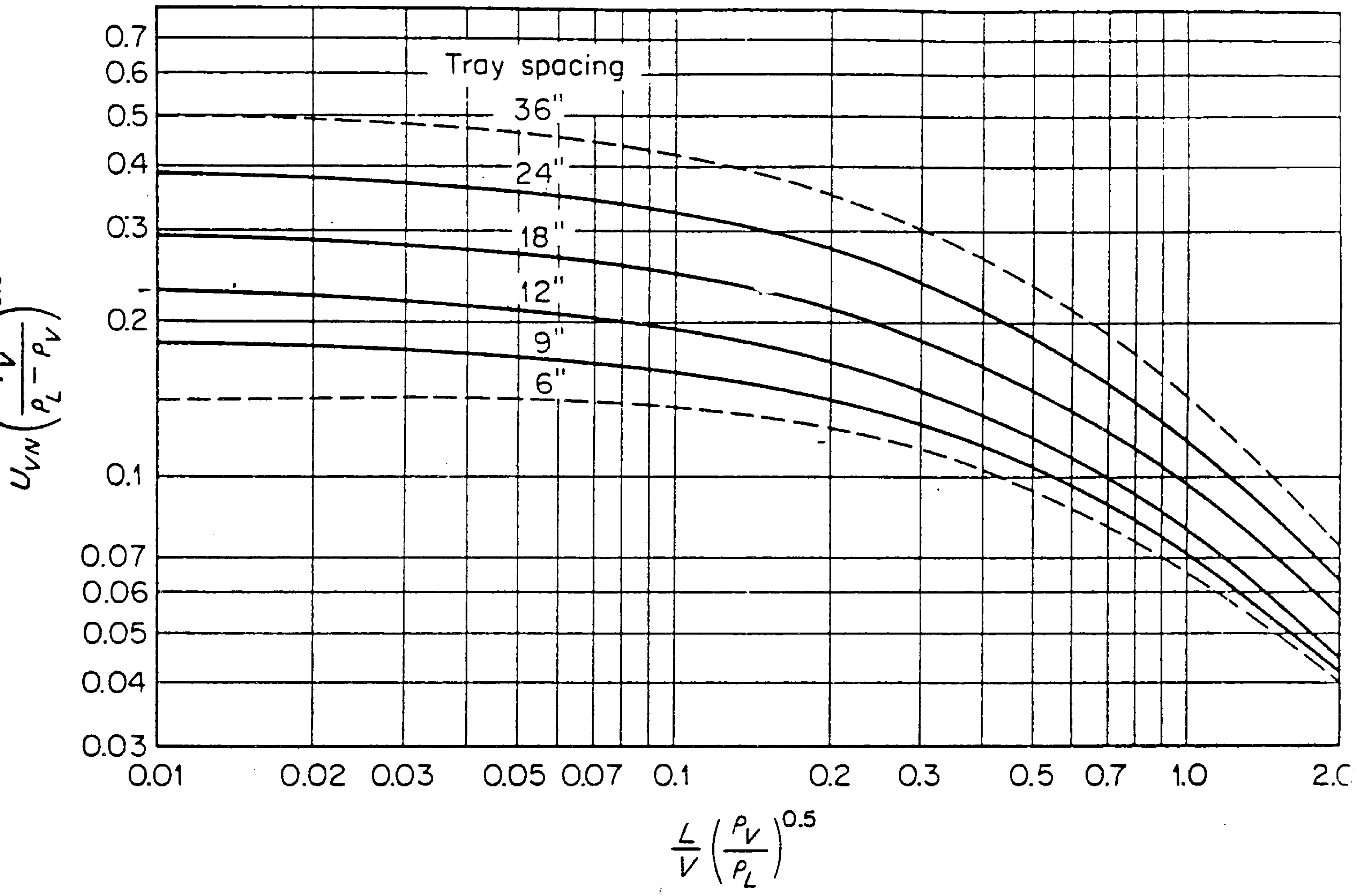


FIG. B7-1 FLOODING LIMITS FOR BUBBLE-CAP AND PERFORATED PLATES [Fair (1961)]

$$D_c = \sqrt{\frac{4V}{\pi \rho_V u}} \qquad \text{...............(B7-3)}$$

and

the height of the column reported by Rathore et al(1974) is given as

$$H_c = 0.61N + 4.27 \qquad \text{...........(B7-4)}$$

[N is the actual number of plates and H_c is the height in meters.]

B-8 Log-Mean Temperature Difference, ΔT_{Ln}

For the condenser,

$$\Delta T_{Ln,c} = \frac{T_2 - T_1}{Ln\left[\frac{T_{sat} - T_1}{T_{sat} - T_2}\right]} \qquad \text{....(B8-1)}$$

where

T_{sat} = saturated temperature of the vapour, K

T_1 and T_2 = inlet and outlet coolant temperature, K

This is the logmean temperature difference for a pure saturated vapour condensing at a fixed temperature and at constant pressure. For most mixtures, this assumption is considered valid [Coulson et al(1983)].

For the reboiler,

The logmean temperature difference, $\Delta T_{Ln,r}$ is simply taken as the difference between the saturated temperatures. This of course is where both the fluid vapour and the steam are at constant temperature.

The $T_{Ln,r}$ used in the study is taken as 25^{o}C [Happel and Jordan(1975), Backhurst and Harker(1981)].

B-9 Energy Flowrates, Q

For the shortcut design method, the energy flowrate is determined using the expression of the form

$$Q_c = Q_r = \lambda\rho_V uA_p \qquad \text{........(B9-1)}$$

For the rigorous procedure, the Q_c and Q_r are given by Equations C1-6 and C1-5 respectively.

B-10 Heat transfer Areas of Condenser and Reboiler, A_c and A_r

For the condenser,

$$A_c = \frac{Q_c}{U_c\ \Delta T_{Ln,c}} \qquad \text{.........(B10-1)}$$

and for the reboiler,

$$A_r = \frac{Q_r}{U_r\ \Delta T_{Ln,r}} \qquad \text{.........(B10-2)}$$

where U is the overall heat transfer coefficient, KJ/m^{2}sec^{o}K whose values for reboiler and condenser are given below in Appendix B-11.

B-11 Cost Analysis

As has been mentioned, the equations employed inthe costing of the columns are those described in section 3.4.1. The particular equations are for

1) Cost of column

$$CC_p = \frac{k_1 N A_p}{E_o} \qquad \ldots\ldots\ldots\ldots(3.5)$$

2) Cost of condenser,

$$C_c = k_2 A_c \qquad \ldots\ldots\ldots\ldots(3.8)$$

3) Cost of Reboiler

$$C_r = k_3 A_r \qquad \ldots\ldots\ldots\ldots(3.11)$$

4) Cost of cooling water

$$C_w = Q_c \frac{C_1 h}{\rho_w C_{pw} \Delta t} \qquad \ldots\ldots(3.12)$$

5) Cost of Steam

$$C_s = Q_r C_2 h / \lambda_s \qquad \text{........(3.15)}$$

The total annual cost, TAC, is

$$TAC = (\mu/k^{-1})(\alpha C_p + C_c + C_r) + C_w + C_s \qquad \text{.....(B11-1)}$$

The summary of the specifications and/or assumptions made in the costs analyses are;

k_1, the unit cost of column/(plate)(area) is 968.72 dollars/m^2.plate

k_2 and k_3, the cost of heat exchanger/unit heat transfer area is 172.22 dollars/m^2.

These cost factors, k_1, k_2 and k_3, are taken from Happel and Jordan(1975) and updated using the Chemical engineering cost index.

unit cost of cooling water, C_1, and heating steam, C_2, are respectively 0.023 dollars/m^3 and 0.02 dollars/Kg. [Bridgewater(1983)].

recovery fraction of feed in the products is 0.99 (except where stated otherwise) feed stream is at the bubble point temperature producing saturated liquid reflux.

tray spacing is constant at 61cm (24ins).

the payout time for the capital investment to be fixed at 3 years.

an installation cost of 1.6 the capital cost of the major equipments.[Peters and Timmerhaus(1980)].

80% flooding capacity is used.

the overall heat tranfer coefficient, U, in the condenser and reboiler taken at values of 0.80 and 1.0 KJ/m^{2}sec K. respectively. This is in accordance with the data in Coulson et al(1983).

the condenser temperature is maintained at 322 Kelvin [Henley and Seader(1981)]. This value of 322 K is choosen because we intend to use water as a cooling medium in the condenser. This temperature sets the column operating pressure. And both the column and condenser pressure drop ar taken to be 5psia.

the condenser and the reboiler logmean temperature differences are as given in Appendix B-8 the maximum allowable vapour velocity based on the total cross-sectional area of the column is as computed in Appendix B-7.

the number of hours of operation per year is 8400.

the operating reflux ratio (unless otherwise specified) is taken as 1.1 times the minimum reflux ratio by Underwood method.

the Chemical Engineering Cost Index of 310.5/125.7 is used.

temperature rise of water is taken as 10 K.

the density of water is $1000 Kg/m^3$.

the specific heat capacity of water is 4.1868 KJ/Kg K.

APPENDIX C

EQUATIONS FOR THE RIGOROUS METHOD COMBINED WITH UNIFACC

C-1 THE RIGOROUS EQUATIONS

As already noted, the rigorous method developed by Naphtali and Sandholm(9171) is used.

Figures C1-1 and C1-2 give the numenclature for any stage n which includes the possibility of feed- and side-streams.

The type of functions, $F_{k(n,i)}$, which describe the physical processes on the plate i and which must be satisfied are;

1) Component Balance (k=1)

$$F_{1(n,i)} = (1 + \frac{S_n^L}{L_n}) l_{n,i} + (1 + \frac{S_n^V}{V_n}) v_{n,i} - v_{n-1,i} - l_{n+1,i} - f_{n,i} = 0 \qquad \ldots\ldots\text{(C1-1)}$$

(n = 2,3,......N-1)

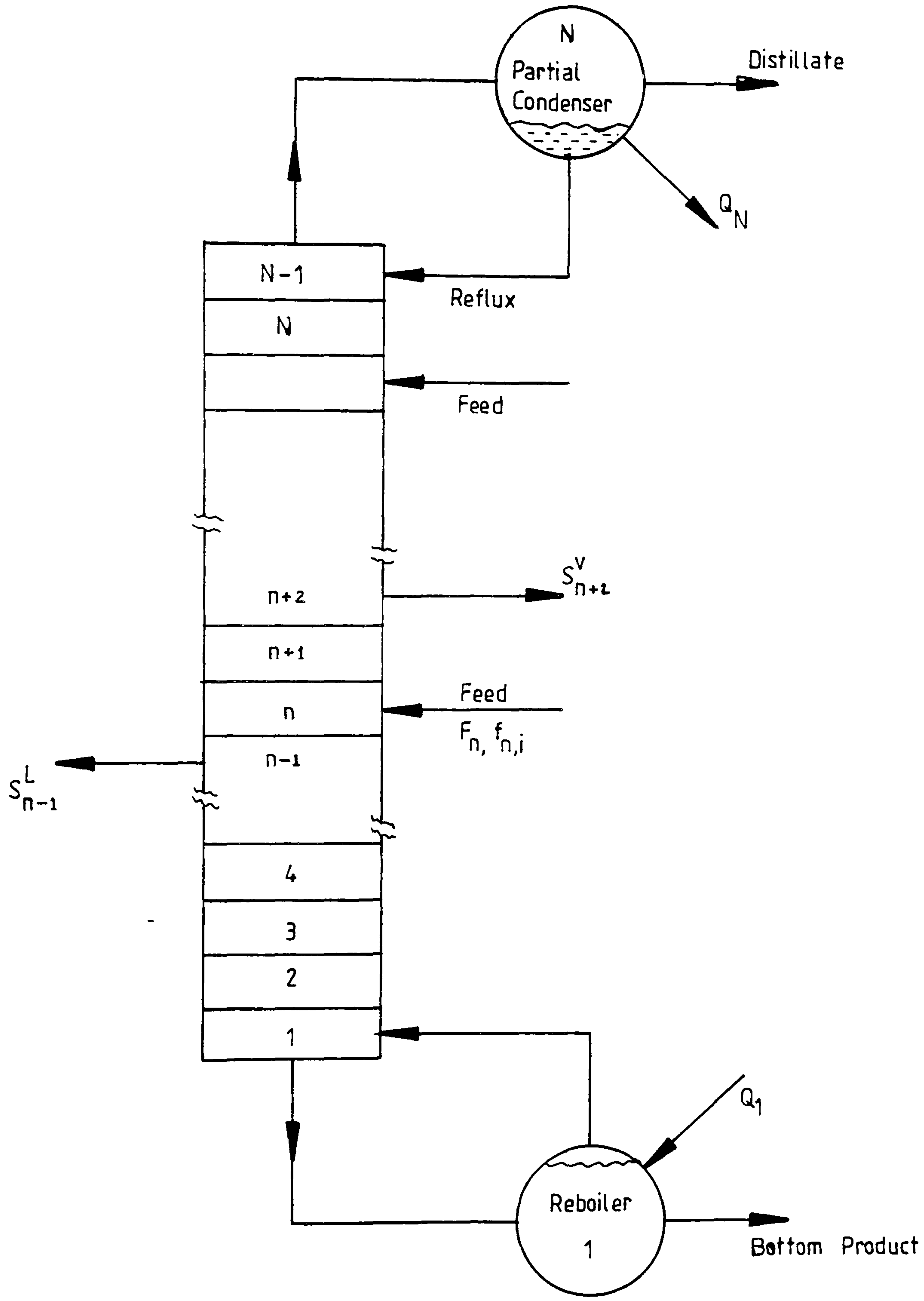
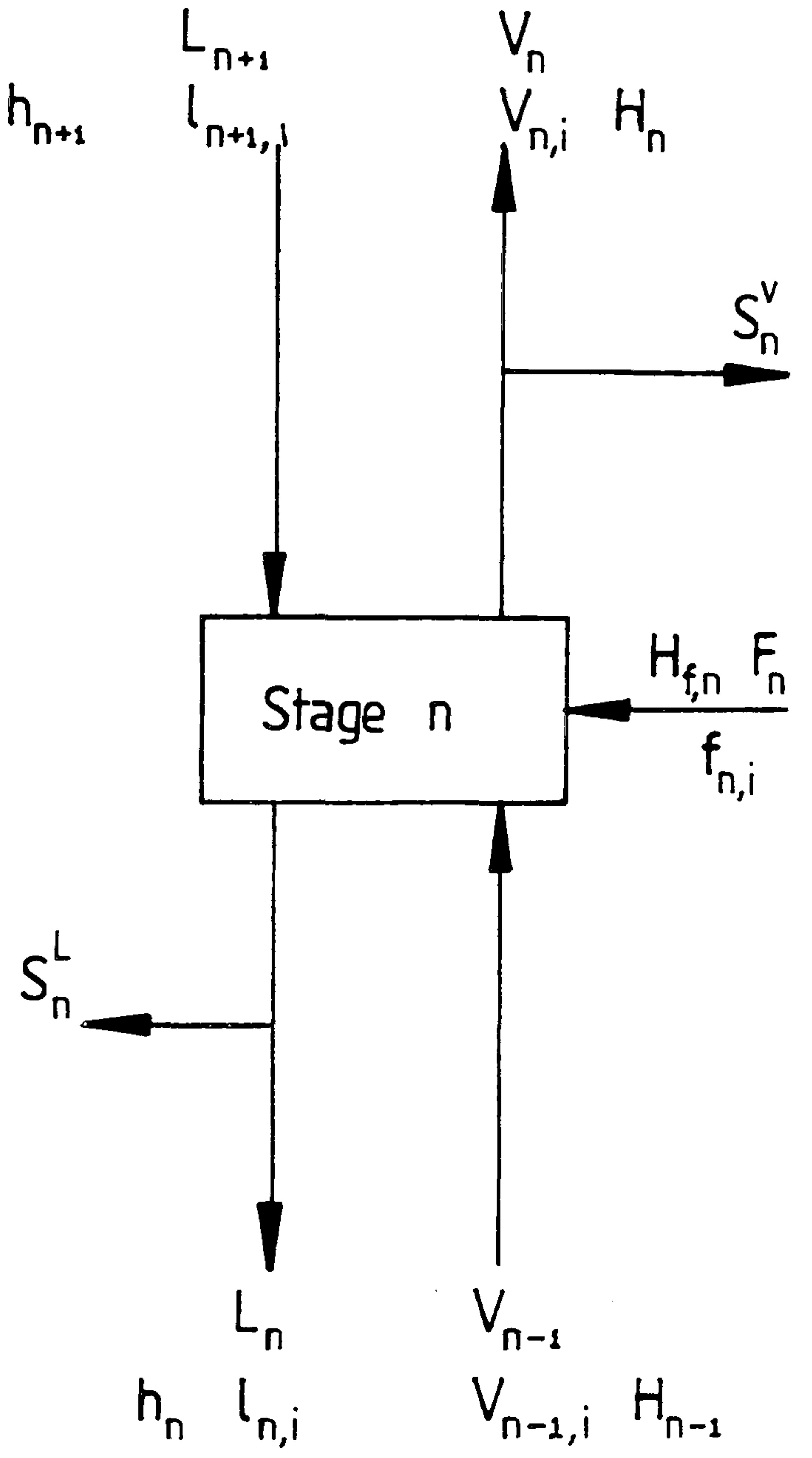


FIG. C1-1 DISTILLATION COLUMN SKETCH



Subscript n: n=1,2,---N

Subscript i: component
i=1,2,----M

H = vapour phase enthalpy

h = liquid phase enthalpy

H_f = feed enthalpy

V = total vapour flow

v = component vapour flow

L = total liquid flow

l = component liquid flow

F = total feed

f = component feed

S^L = liquid side stream

S^V = vapour side stream

FIG. C1-2 NOMENCLATURE FOR AN ARBITRARY STAGE, N, IN A DISTILLATION COLUMN

[In the equations, N is the total number of stages including the reboiler (n=1) and the partial condenser (n=N), and m is the total number of components. Note too that in this appendix, S refers to a sidestream rate.]

$$F_{1(1,i)} = (1 + \frac{S_1^L}{L_1}) l_{1,i} + (1 + \frac{S_1^V}{V_1}) v_{1,i} - l_{2,i} - f_{1,i} = 0 \quad ..(C1\text{-}2)$$

$$F_{1(N,i)} = (1 + \frac{S_N^L}{L_N}) l_{N,i} + (1 + \frac{S_N^V}{V_N}) v_{N,i} - v_{N-1,i}$$
$$- v_{N-1,i} - f_{N,i} = 0 \quad ......(C1\text{-}3)$$

V_N is the distillate and L_1 the bottom product.

Equations C1-1 to C1-3 comprise N*M relationships.

2) Energy Balances (k=2) ; Index i drop out

$$F_{2(n)} = (1 + \frac{S_n^L}{L_n}) h_n + (1 + \frac{S_n^V}{V_n}) H_n - H_{n-1} - h_{n+1} - h_{f,n} = 0 \quad ..(C1\text{-}4)$$

(n = 2,3,4 .....N-1)

$$Q_1 = Q_r = (1 + \frac{S_1^L}{L_1}) h_1 + (1 + \frac{S_1^V}{V_1}) H_1 - h_2 - h_{f,1} \quad ....(C1\text{-}5)$$

$$Q_N = Q_c = (1 + \frac{S_N^L}{L_N}) h_N + (1 + \frac{S_N^V}{V_N}) H_N - H_{N-1} - h_{f,N} \quad ....(C1\text{-}6)$$

Equations C1-5 and C1-6 could be used to generate $F_{2(1)}$ and $F_{2(N)}$ if the heat removed from the condenser, Q_N, and the heat added to the reboiler Q_1 were specified variables.

However, in our case, the reflux ratio, R, and the distillate flow, V_N, are specified. In this case Equations C1-5 and C1-6 are used to calculate Q_1 and Q_N and the following functions are chosen to replace them.

$$F_{2(1)} = \sum_{i}^{M} l_{1,i} - L_1 = 0 \qquad \text{........(C1-7)}$$

where from a total column material balance,

$$L_1 = \sum_{i}^{N} \sum_{i}^{M} f_{n,i} = V_N - \sum_{i}^{N} (S_n^L + S_n^V)$$

(n=1,2,....N)

$$F_{2(N)} = \sum_{i}^{M} l_{N,i} - L_N = 0 \qquad \text{........(C1-8)}$$

where $L_N = R.V_N$

Equations (C1-4), (C1-7) and (C1-8) comprise N functions.

3) Equilibrium Relationship (k=3)

The Murphree stage efficiency is defined by

$$\eta_{n,i} = \frac{y_{n,i} - y_{n-1,i}}{K_{n,i}x_{n,i} - y_{n-1,i}} \qquad \text{.........(C1-9a)}$$

where

$$K_{n,i} = \left[\frac{y_i}{x_i}\right]_n = \left[\frac{\gamma_i f_i^o}{\Phi_i P}\right]_n \qquad \text{..........(C1-9b)}$$

where

γ_i = liquid activity coefficient

Φ_i = vapour fugacity coeficient

P = total column pressure

f_i^o = the fugacity of pure componet i at the system temperature and pressure.

Rearranging Equation (C1-9) gives the following functions

$$F_{3(n,i)} = \eta_{n,i}K_{n,i}x_{n,i} - y_{n,i} + (1 - \eta_{n,i})y_{n-1,i} \qquad \text{....(C1-10a)}$$

or

$$F_{3(n,i)} = \eta_{n,i}K_{n,i}V_n \frac{l_{n,i}}{L_n} - v_{n,i} + (1 - \eta_{n,i})*$$

$$V_n \frac{v_{n-1,i}}{V_{n-1}} = 0 \qquad \text{..........(C1-10b)}$$

For the reboiler, the efficiency is 1.0, that is

$$\eta_{n,i} = 1 \text{ ; for all i}$$

There are N.M equations of the type k=3. It is in this Equation (C1-10) that UNIFAC method enters into the calculations via the equilibrium ratio, $K_{n,i}$.

All these functions ($F_{k(n,i)}$) are termed the discrepancy functions, that is, they are a quantitative measure of the failure of the values of $L_{n,i}$, $V_{n,i}$ and T_n to satisfy the physical relationships.

In terms of algebra, Equations C1-1 to C1-4, C1-7, C1-8, and C1-10 comprise a vector discrepancy functions:

$$\bar{F}(\bar{x}) = \begin{bmatrix} \bar{F}_1 \\ \bar{F}_2 \\ \bar{F}_3 \end{bmatrix} = 0 \qquad \text{...........(C1-11)}$$

which contains N.(2M+1) elements and which may be solved for the same number of unknown (independent variables):

$$\bar{x} = \begin{bmatrix} \bar{l} \\ \bar{v} \\ \bar{T} \end{bmatrix} \qquad \text{..............(C1-12)}$$

where the vector $\bar{l}$ contains all the elements $l_{n,i}$; $\bar{v}$ all elements $v_{n,i}$ and $\bar{T}$ all the elements T_n.

Equation (C1-11) is solved by Newton-Raphson iteration utilizing simultaneous convergence of all the independent variables, $\bar{x}$. Solving the equations means finding the set of values of the independent variables, $\bar{x}$, which makes the set of discrepancy functions become equal to zero:

$$\bar{F}(\bar{x}) = 0$$

In the Newton-Raphson iteration, a new set of values of the independent variables $\bar{x}_r$ is generated from a previous estimate, $\bar{x}_{r-1}$ in the following fashion:

$$\bar{x}_r = \bar{x}_{r-1} - \bar{F}_{r-1}(\bar{x}_{r-1}) \left[\frac{\bar{\bar{dF}}}{\bar{dx}}\right]^{-1} \Bigg|_{n-1} \quad \text{.......(C1-13)}$$

The variations between subsequent iterations are arbitrarily limited as follows:

(i) negative component molar flow rates are equated to zero.

(ii) component flow rates exceeding L_n are equated to L_n.

(iii) the maximum change in the temperature ts each stage, T_n is 10 K.

$\frac{\bar{\bar{dF}}}{\bar{dx}}$ is the matrix af partial derivatives of all the functions with respect to all the variables at the present value of the variable $\bar{x}_{r-1}$.

It will be noted that the discrepancy functions for plate n [Equations C1-1, C1-2, and C1-3] involve only variables on the plate n-1, n, and n+1. Thus the partial derivatives of the functions on this plate with respect to the variables on all other than these three are zero. Thus the partial derivative equation turns out to be a block diagonal structure. This simplifies the solution.

All the equations given so far in this appendix C-1 are taken from Naphtali and Sandholm(1971) and Fredenslund et al(1977). Further details can be obtained from these references.

The way this procedure is utilized in the distillation column calculations is shown in the flowchart of Figure F-3 in Appendix F.

C-2 UNIFAC Group-Contribution Method.

The UNIFAC method was proposed by Fredenslund et al(1975) and this was based on the UNIQUAC model [Abrams and Prausnitz(1975)] for liquid mixture. The UNIFAC method is used to predict the liquid phase activity coefficients for non-ideal mixtures even when experimental phase equilibrium are not available.

In a multicomponent mixture, the UNIQUAC equation for the activity coeffiecient consists of two parts: the combinatorial part which relates to the difference in molecular size and shape, and the residual part which relates to energetic interactions between the molecules. As a consequence the activity coefficient is given as

$$\mathrm{Ln}\ \gamma_i = \mathrm{Ln}\ \gamma_i^C + \mathrm{Ln}\ \gamma_i^R \qquad \text{.............(C2-1)}$$

where γ^C is the combinatorial part, and γ^R the residual part.

But

$$\mathrm{Ln}\ \gamma_i^C = \mathrm{Ln}\ \frac{\phi_i}{x_i} + \frac{z}{2} q_i \mathrm{Ln}\ \frac{\theta_i}{\Phi_i} + l_i - \frac{\phi_i}{x_i} \Sigma_j x_j l_j \qquad \text{.....(C2-2)}$$

and

$$\mathrm{Ln}\ \gamma_i^R = q_i[1 - \mathrm{Ln}(\Sigma\ \phi_j\ \tau_{ji}) - \Sigma\ (\phi_j\ \tau_{ij})/\ \theta_k\ \tau_{kj})] \qquad \text{...............(C2-3)}$$

$$l_i = \frac{z}{2}(r_i - q_i) - (r_i - 1) \qquad \text{....................(C2-4)}$$

$$z = 10 \qquad \text{.................(C2-5)}$$

$$\theta_i = \frac{q_i x_i}{\sum q_j x_j} \qquad \text{.............(C2-6)}$$

$$\phi_i = \frac{r_i x_i}{\sum r_j x_j} \qquad \text{.............(C2-7)}$$

$$\tau_{ij} = \exp-[\frac{u_{ij} - u_{ii}}{RT}] \qquad \text{...........(C2-8)}$$

(i and j = 1,2, M (number of components))

In these equations, x_i is the mole fraction of component i and the summations in Equations C2-2 and C2-3 are over all components including component i, θ_i is the area fraction and ϕ_i is the segment fraction which is similar to the volume fraction. Pure component parameters r_i and q_i are respectively measures of molecular van der Waals volume and molecular surface areas. The two adjustable binary parameters τ_{ij} and τ_{ji} must be evaluated from experimental equilibrium data.

In the UNIFAC, the combination part of the UNIQUAC activity coefficient is used directly wherein the molecular volume and the area parameters in the combinatorail terms are replaced by

$$r_i = \sum y_k^{(i)} R_k \qquad \text{..............(C2-9)}$$

$$q_i = \sum y_k^{(i)} Q_k \qquad \text{..............(C2-10)}$$

(k=1,2,....N (no. of different groups in molecule i), wherein $y^{(i)}$ is the number of functional groups of type k in the molecule i, and R_k and Q_k are the volume and area parameters respectively for type-k functional group. R_k and Q_k are obtained from the van der Waals group volume and surface areas V_{wk} and A_{wk}.

$$R_k = V_{wk}/15.17$$

$$Q_k = A_{wk}/(2.5*10^9)$$

The calculation of $y^{(i)}$ for example, is illustrated by the example of Diethyl amine and n-Heptane mixture:

For Diethyl Amine has $2CH_3$, $1CH_2$ and $1CH_2NH$;

n-Heptane has $2CH_3$m and $5CH_2$

The molecular functional group table will look like this

$y^{(i)}$

Group	Diethyl amine	n-Heptane
CH_3	2	2
CH_2	1	5
CH_2NH	1	0

The residual part of the activity coefficient for the UNIQUAC is replaced by the solution-of-group concept. Instead of equation C2-3, we write

$$\mathrm{Ln}\,\gamma_i^R = \Sigma y_k^{(i)}[\mathrm{Ln}\,\Gamma_k - \mathrm{Ln}\,\Gamma_k^{(i)}] \qquad ....(C2-11)$$

Γ_k is the residual activity coefficient of group k in a solution; $\Gamma_k^{(i)}$ is the residual activity coefficient of group k in a reference solution containing only molecules of type i

Γ_k is found from an expression similar to C2-3

$$\mathrm{Ln}\ \Gamma_k = Q_k[1 - \mathrm{Ln}(\Sigma \Theta_m \Psi_{mk}) - \Sigma\ (\Theta_m \Psi_{km})/ \Sigma \Theta_n \Psi_{nm})] \qquad \text{..............(C2-12)}$$

(m and n = 1,2,3 ..N (all groups)). Note that this is for a particular group k.

This Equation C2-12 holds for Ln $\Gamma_k^{(i)}$.

Θ_m is the area fraction of group m, and the sums are over all different groups. It is calculated in a manner similar to Θ_i

$$\Theta_m = \frac{Q_m X_m}{\Sigma Q_n X_n} \qquad \text{..........(C2-13)}$$

and

$$X_m = \frac{\Sigma y_m^{(i)} x_j}{\sum\limits_j \sum\limits_n y_n^{(i)} x_j} \qquad \text{..........(C2-14)}$$

(j=1,2,......M (all compounds or components))

and the group interraction parameters between group n and m, Ψ_{nm}, is given by an expression similar to C2-8

$$\Psi_{nm} = \exp[-a_{nm}/T] \qquad \text{.........(C2-15)}$$

where $a_{nm} \neq a_{nm}$

This group interaction parameter, a_{nm}, (two parameters for binary mixture of groups) are the parameters which must be evaluated from the experimental phase equilibrium data. Tables of values for R_k, Q_k, a_{nm} and a_{mn} are available, though not for most components at the moment [Gmehling et al(1982), Macedo et al(1983)].

The assumptions made in the derivations of the above equations are given by Fredenslund et al(1975,1977).

Some of the advantages of the UNIFACC method over other group contribution methods are:

(1) It is theoretically based onthe UNIQUAC method.

(2) the parameters are essentially independent of temperature.

(3) size and binary interaction parameters are available for a wide range of types of functional groups.

(4) predictions can be made over a temperature range of 275 to 425 K and for pressures up to few atmospheres.

(5) It can be applied to liquid-liquid and vapour liquid liquid systems.

However, the range of applicability of UNIFAC is limited because of

(1) limitations of the activity coefficiet approach (e.g. low to moderate pressure limit).

(2) restriction stemming from the assumptions of the solution-of-group approach.

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The units are Kelvin, atmosphere and cubic centimeter per gram mole. The Δ quantities are evaluated summing contributions for various atoms or group of atoms as reported in Reid et al(1977). T_b is the normal boiling point temperature and MW is the molecular weight. R is the gas constant in atm.cm^3/(gmole ^{o}K) and this is equal to 82.057.

D-2 Antoine Parameters and Vapour Pressure, P^{o}

The relations are [Reid et al(1977)]

$$C = -18 + 0.19\ T_b \qquad \text{..........(D2-1)}$$

$$B = (1/\ \Delta Z_{vb})(T_b - C)^2\ \frac{b}{2.303RT_b^2} \qquad \text{......(D2-2)}$$

[For very high pressures, $(1/\ \Delta Z_{vb}) = 1.05$]

$$A = B/(T_b - C) \qquad \text{.............(D2-3)}$$

(R = 1.986 cal/gmole K)

λ_b is the latent heat of vapourization in cal/gmol at the normal boiling point is given as

$$\lambda_b = R\ T_c T_{br} \left[\frac{3.978T_{br} - 3.938 + 1.555\text{Ln}\ P_c}{1.07 - T_{br}}\right] \qquad \text{.....(D2-4)}$$

T_{br} is the reduced temperature at the normal boiling point, T_b.

The equations D2-1 to D2-4 as given applied to the Antione equation of the form

(3) lack of reliable data to compile interaction parameters.

(4) lack of flexibility of the UNIFAC functional expressions. For instance, separate group-interaction parameter tables had to be developed for VLE and LLE calculations.

APPENDIX D

SOME PHYSICAL AND THERMAL PROPERTIES.

The property data bank covers a wide range of physical properties which are either taken from textbooks or calculated using some known correlations. It is the correlations used that are given here. They are used only where experimental data are not found. This happens for very few components in the data bank.

D-1 Critical Properties, P_c, T_c, V_c, Z_c

The estimation method used is the Lydersen's method(1955). It employs structural contributions to estimate critical temperature, T_c, critical pressure, P_c and critical volume, V_c. The relations are

$$T_c = T_b[0.567 + \Sigma\,\Delta_T - (\Sigma\Delta_r)^2]^{-1} \quad \ldots\ldots\ldots(D1\text{-}1)$$

$$P_c = MW[0.34 + \Sigma\Delta_P]^{-2} \quad \ldots\ldots\ldots(D1\text{-}2)$$

$$V_c = 40.0 + \Sigma\,\Delta_V \quad \ldots\ldots\ldots(D1\text{-}3)$$

$$Z_c = P_c V_c/(RT_c) \quad \ldots\ldots(D1\text{-}4)$$

$$\mathrm{Log}\ P^{o} = A - \frac{B}{T - C} \qquad \text{..........(D2-5)}$$

But the form used in this work is

$$\mathrm{Ln}\ P^{o} = A' - \frac{B'}{T + C'} \qquad \text{...........(D2-6)}$$

Therefore,

$$C' = -C$$

$$B' = B * 2.30258$$

$$A' = \frac{B'}{T_b - C'} * 2.30258$$

D-3 Acentric Factor, ω

Edmister(1958) equation

$$\omega = \frac{3}{7}\,\frac{T_{br}}{1 - T_{br}}\,\mathrm{Log}\ P_c - 1 \qquad \text{..........(D3-1)}$$

or

Pitzer(1955)'s correlation

$$\omega = -\mathrm{Log}\ P^{o}\ (\text{at } T_r = 0.70) - 1.0 \qquad \text{.......(D3-2)}$$

is used for the estimation of the acentric factor.

D-4 Liquid Density, ρ_L

The Gunn and Yamada(1964)'s equation is used

$$\frac{V}{V_{sc}} = V_r^{(o)}(1 - \omega\,\Gamma) \qquad \text{..........(D4-1)}$$

where V = liquid specific volume, $cm^3/gmol$.

V_{sc}= scaling parameter which is defined in terms of volume at $T_r = 0.60$ as

$$V_{sc} = \frac{V_{0.6}}{0.3862 - 0.0866\ \omega} \qquad \text{(D4-2)}$$

or

$$V_{sc} = \frac{R\ T_c}{P_c}(0.29920 - 0.0967\ \omega) \qquad \text{(D4-3)}$$

for

$0.2 < T_r < 0.8$

$$V_r^{(o)} = 0.33593 - 0.33953T_r + 1.51941T_r^2 - 2.02512T_r^3 + 1.11422T_r^4 \qquad \text{(D4-4)}$$

for $0.8 < T_r < 1.0$

$$V_r^{(o)} = 1.0 + 1.3(1 - T_r)^{0.5}\text{Log}(1 - T_r) - 0.50879(1 - T_r) - 0.91534(1 - T_r) \qquad \text{(D4-5)}$$

for $0.2 < T_r < 1.0$

$$\Gamma = 0.29607 - 0.09045\ T_r - 0.04842\ T_r^2 \qquad \text{(D4-6)}$$

The liquid density is calculated as

$$\rho_L = 1/V \qquad \text{(D4-7)}$$

D-5 Vapour and Liquid capacities and Enthalpies.

The ideal gas state heat capacity (in cal/gmol K) is calculated as a polynomial

$$C_p^o = a + bT + cT^2 + dT^3 \qquad \text{..........(D4-8)}$$

The constants are estimated by the group contribution method suggested by Rihani and Doraiswamy(1965). The equation D5-1 is not corrected for pressure effects on non-ideal vapour as this correction factor is found to be very small in most cases. [Pan and Maddox(1981)].

For the liquid capacity, C_{PL}, the modification of the Rowlinson(1969) correlation proposed by Bondi(1966) is used.

$$C_{PL} - C_P^o = 2.56 + 0.436(1 - T_r)^{-1} + w\,[2.91 + 4.28(1 - T_r)^{0.333333}T_r^{-1} + 0.296(1 - T_r)^{-1}] \qquad \text{..(D5-2)}$$

These equations D5-1 and D5-2 are used to evaluate the enthalpy for each component. The total enthalpy of a phase as given by Frendenslund et al(1977) is defined by a linearized equation such that the enthalpy for a liquid is

$$h = h_o + C_{PL}t \qquad \text{..........(D5-3)}$$

and for a vapour

$$H = H_o + C_p^o\,t \qquad \text{..........(D5-4)}$$

The temperature denoted by t is referred to any standard state temperature, t_o, which usually is taken to be 25°C. H_o and h_o are the vapour and liquid enthalpies of pure components in cal/gmol.

Having known C_{PL}, C_P^o and λ^o, the heat of evaporation at the standard temperature, the parameters are defined as follows:.

$$h_o = - C_{PL} . t_o \qquad \text{.........(D5-5)}$$

$$H_o = \lambda^o - C_P^o . t_o \qquad \text{.........(D5-6)}$$

The latent heat of vaporisation at any temperature is calculated by the relationship suggested by Watson(1943).

$$\lambda = \lambda_b [(1 - T_r)/(1 - T_{rb})]^{0.38} \qquad \text{......(D5-7)}$$

D-6 Radius of Gyration, R_D

Radius of Gyration may be calculated by an equation reported by Fredenslund et al(1977). This is

$$R_D = - 0.2764 + 0.2697 (P'' - 48.95)^{0.5} \qquad \text{.....(D6-1)}$$

where P" = parachor parameter which can be obtained for most component from Quale(1953)'s data.

D-7 Fugacity Coefficients

For phase equilibrium,

$$f_i^V = f_i^L \qquad \text{.........} (D7\text{-}1)$$

where f_i is the fugacity of component i in the vapour, V, or liquid, L, phase.

The vapour fugacity for an ideal vapour is given by

$$f_i^V = y_i P \qquad \text{...........} (D7\text{-}2)$$

and for a non-ideal vapour is

$$f_i^V = y_i P \phi_i \qquad \text{...............} (D7\text{-}3)$$

The fugacity coefficient ϕ can be obtained from the virial equation. From basic thermodynamic manipulations,

$$\mathrm{Ln}\, \phi_i = \frac{1}{RT} \int_0^P (v_i - \frac{RT}{P})dP \qquad \text{.....} (D7\text{-}4)$$

where v is the partial molar volume.

At pressure up to a few atmospheres, the volume explicit virial equation may be truncated after the second term:

$$Z = \frac{P\ v}{R\ T} = 1 + \frac{BP}{RT} \qquad \text{..........} (D7\text{-}5)$$

where v is the molar volume. And in a mixture of M components

$$B = \sum_{i=1}^{M} \sum_{j=1}^{M} y_i y_j B_{ij}(T) \qquad \text{......} (D7\text{-}6)$$

The B_{ij}'s represent interaction between molecules i and j. Combininination of equations D7-4, D7-5 and D7-6 gives

$$\text{Ln } O_i = \frac{P}{RT} [2 \sum_{j=1}^{M} y_i B_{ij} - B] \qquad \text{...........(D7-7)}$$

Hayden and O'Connell(1975) have shown that the total virial coefficient can be taken as the sum of several contributions.

$$B_{total} = B_{free} + B_{metastable} + B_{bound} + B_{chem} \text{......(D7-8)}$$

B_{free} represents the molecular volumes; and the contribution of $B_{metastable} + B_{bound}$ results from the potential energy from more or less strongly bound pairs of molecules and B_{chem} results from associating substances. The authors (Hayden and O'Connell(1975) developed equations for estimating the parameters in Equation (D7-8). It is not necessary to go through the derivations of the equations here.

APPENDIX E

SEQUENCES OF DISTILLATION COLUMNS

The number of possible sequences of distillation column trains increases more rapidly as the number of components in the feed increaeses. The number of sequences, S_E, for M components and for R separation types is expressed in the following equation

$$S_E = \frac{[2(M - 1)]!\ R^{M-1}}{M!\ (M - 1)!} \qquad \text{......(E1-1)}$$

Evaluation of this equation for up to ten components in the feed and for one separation type is shown in the table below.

TABLE E1-1: Number of sequences against number of components.

No. of components	No. of sequences	No. of unique separations.
2	1	1
3	2	4
4	5	10
5	14	20
6	42	35

TABLE E1-1: (Continued)

No. of components	No. of sequences	No. of unique separations.
7	132	56
8	429	84
9	1430	120
10	4862	165

In the rest of this appendix, the process topology for three-, four-, five- and six-component mixtures is given.

For a 3-component mixture (2 Sequences)

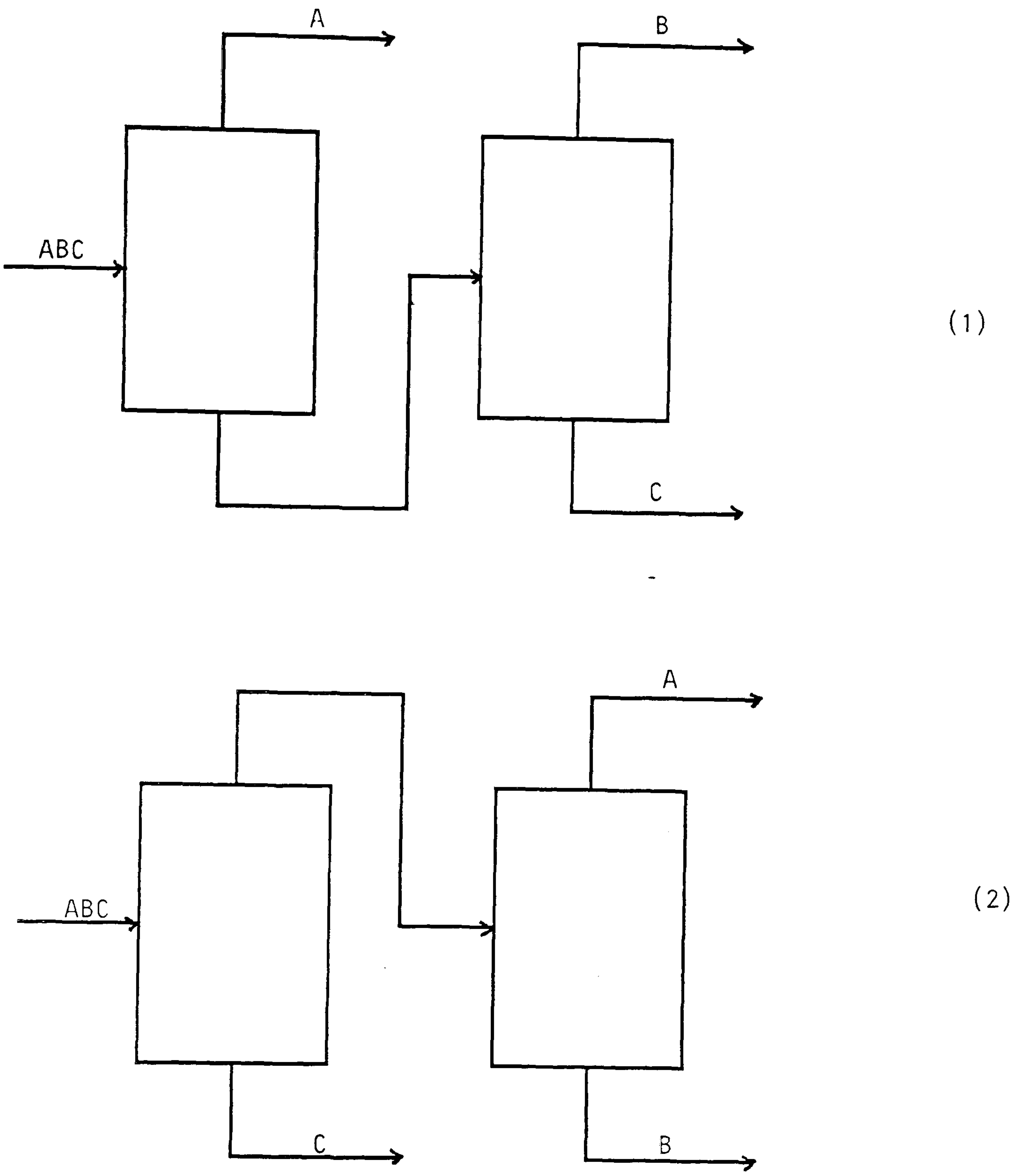


FIG. E1-1 POSSIBLE NUMBER OF SEQUENCES FOR A THREE-COMPONENT MIXTURE

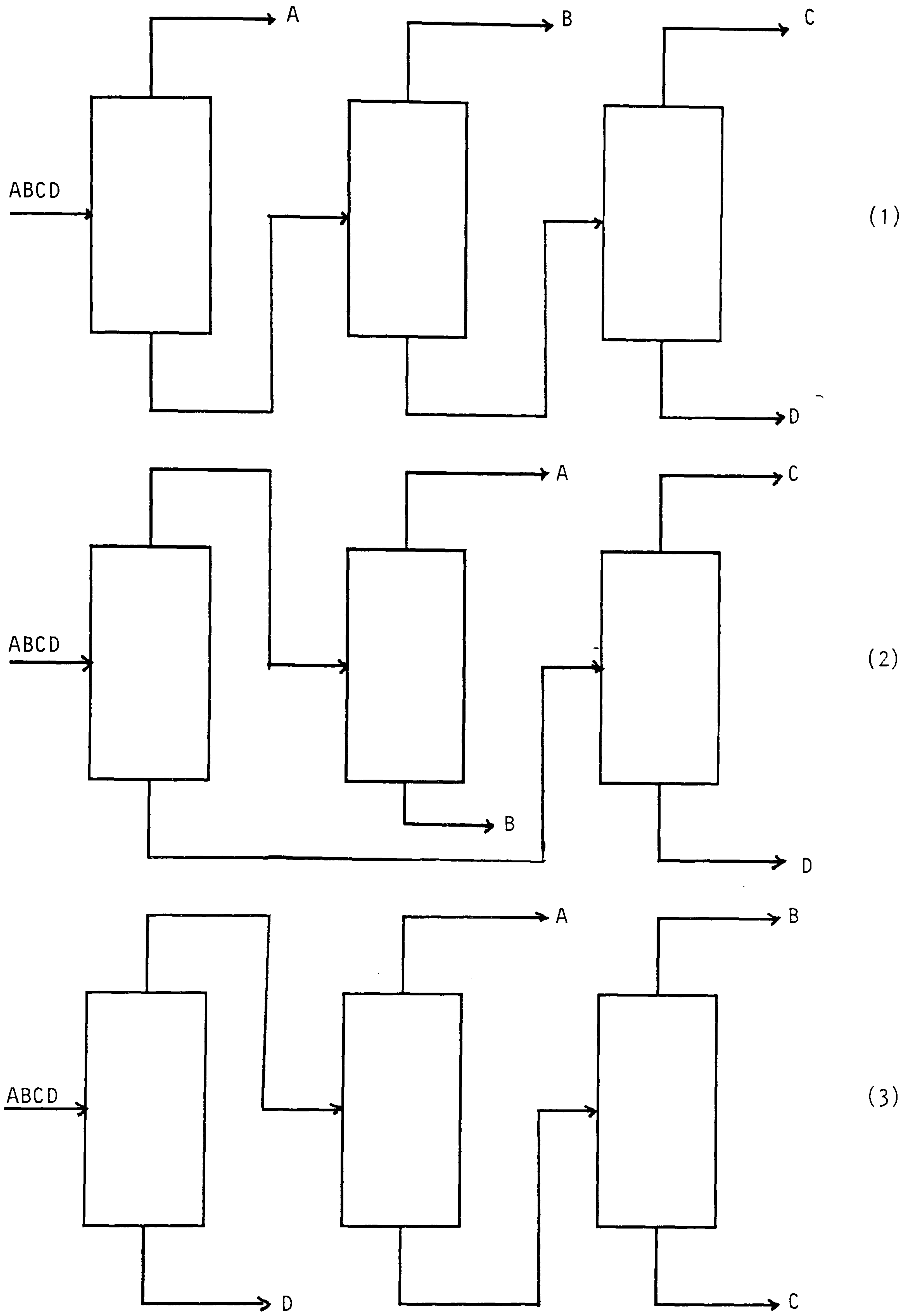
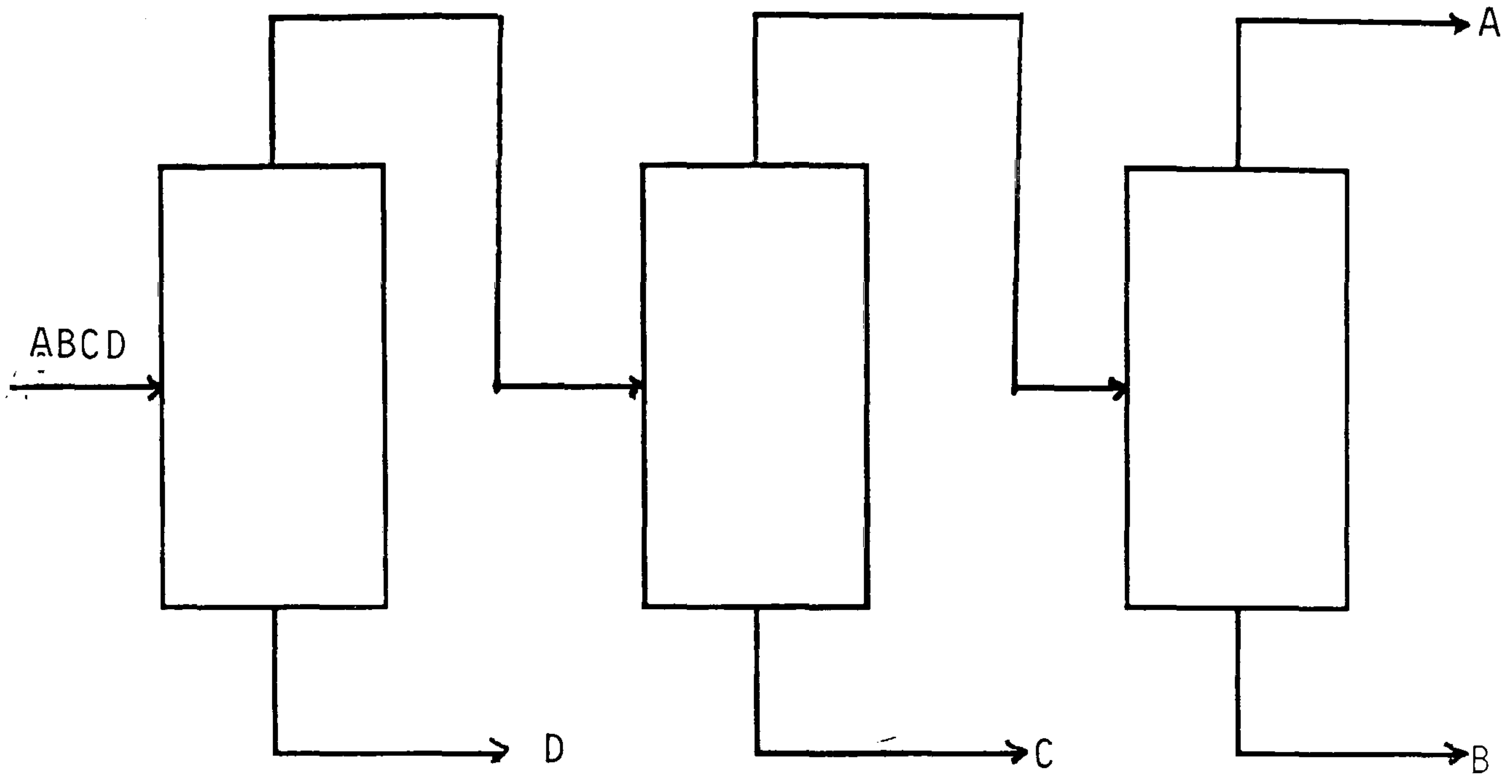
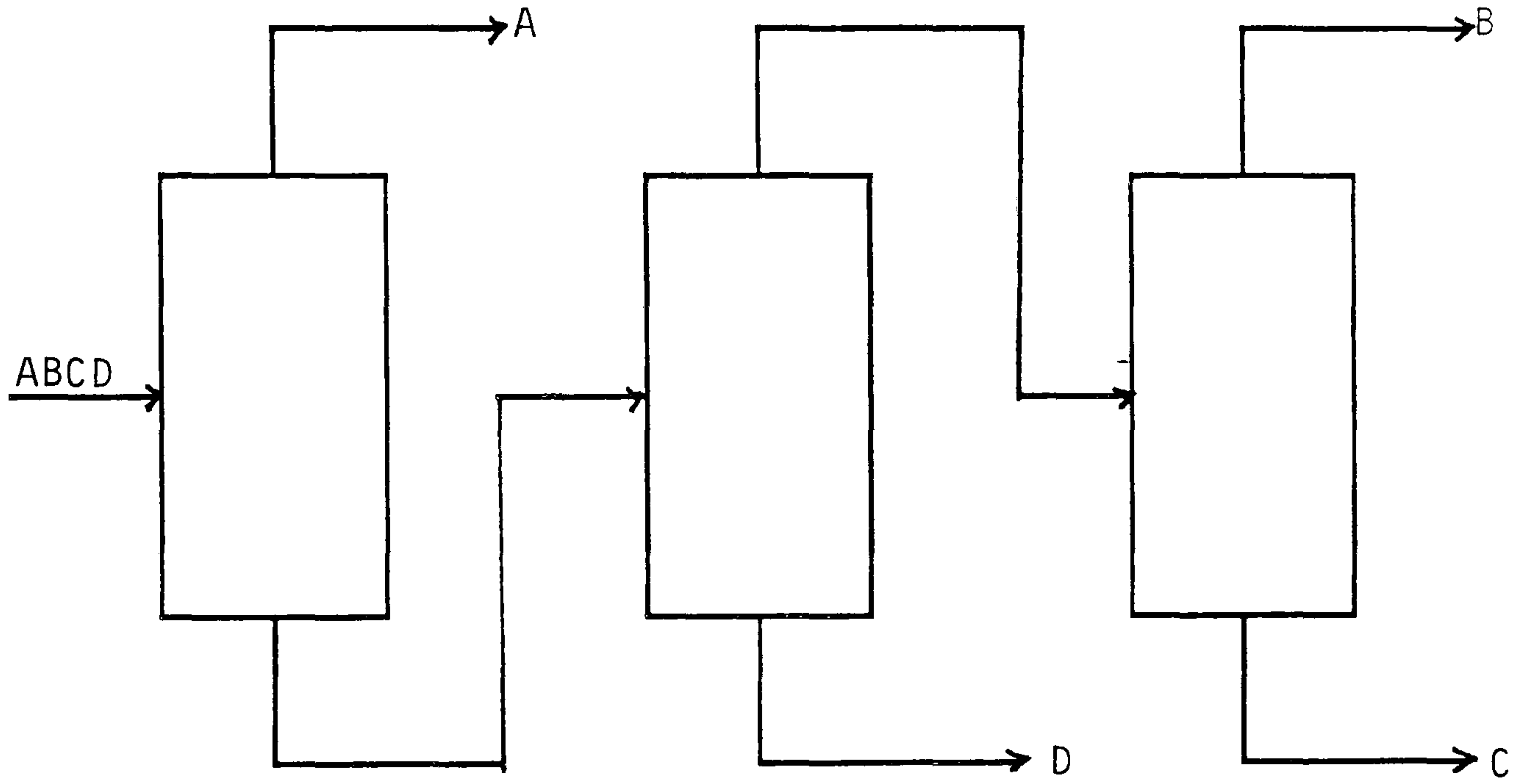


FIG. E1-2 POSSIBLE NUMBER OF SEQUENCES FOR A FOUR-COMPONENT MIXTURE .



(4)



(5)

FIG. E1-2 (CONTINUED)

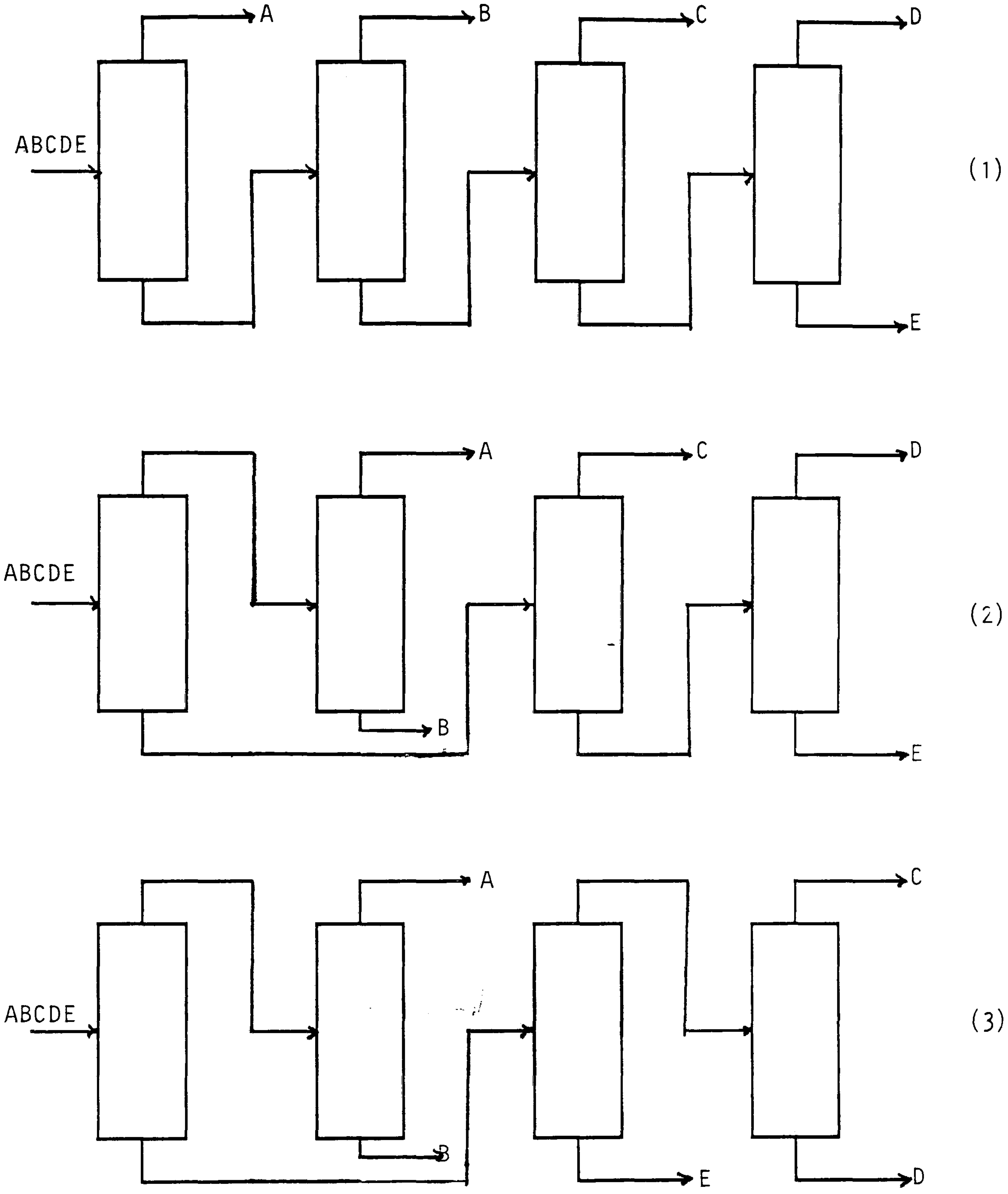


FIG. E1-3 POSSIBLE NUMBER OF SEQUENCES FOR A FIVE-COMPONENT MIXTURE

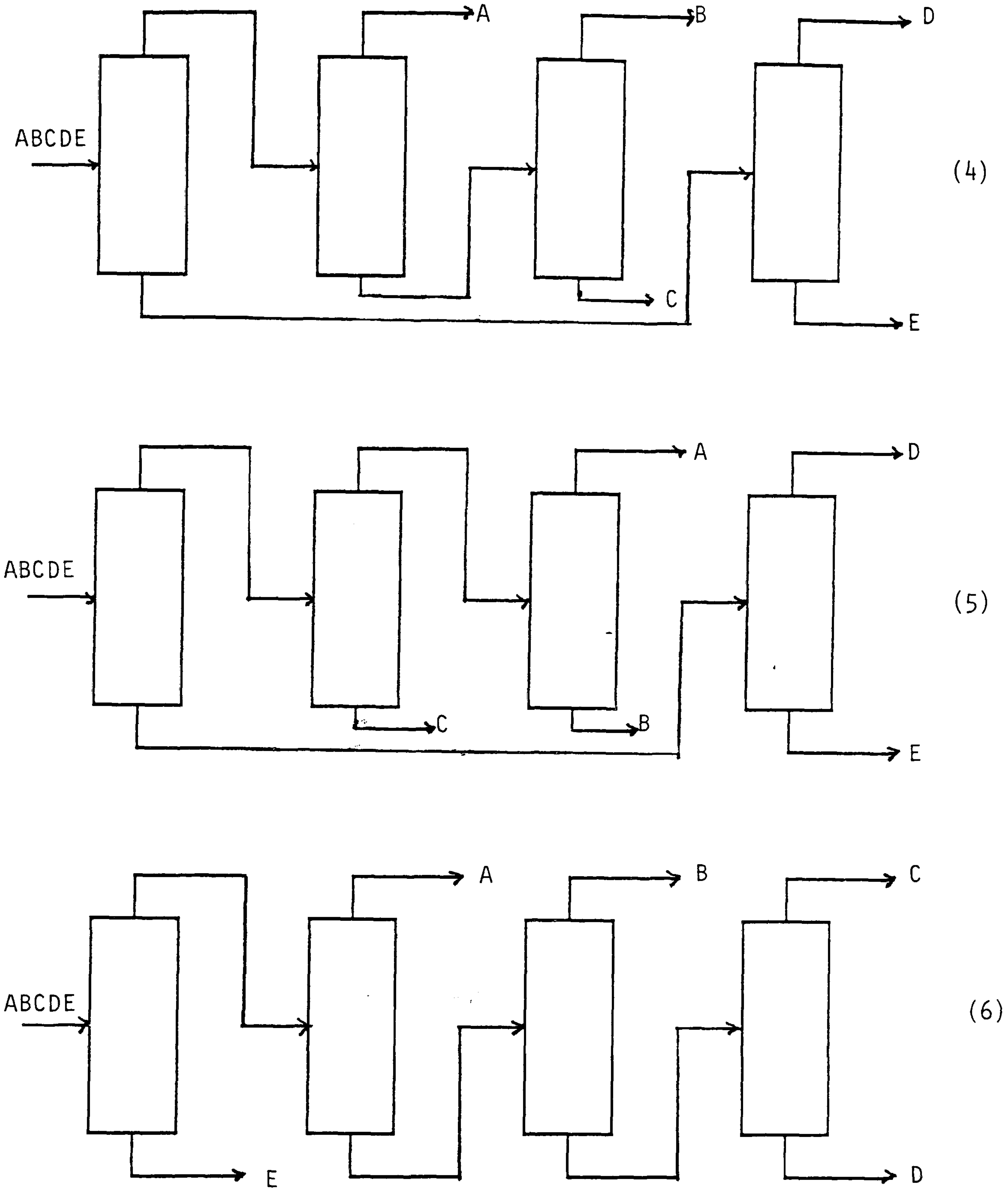


FIG. E1-3 (CONTINUED)

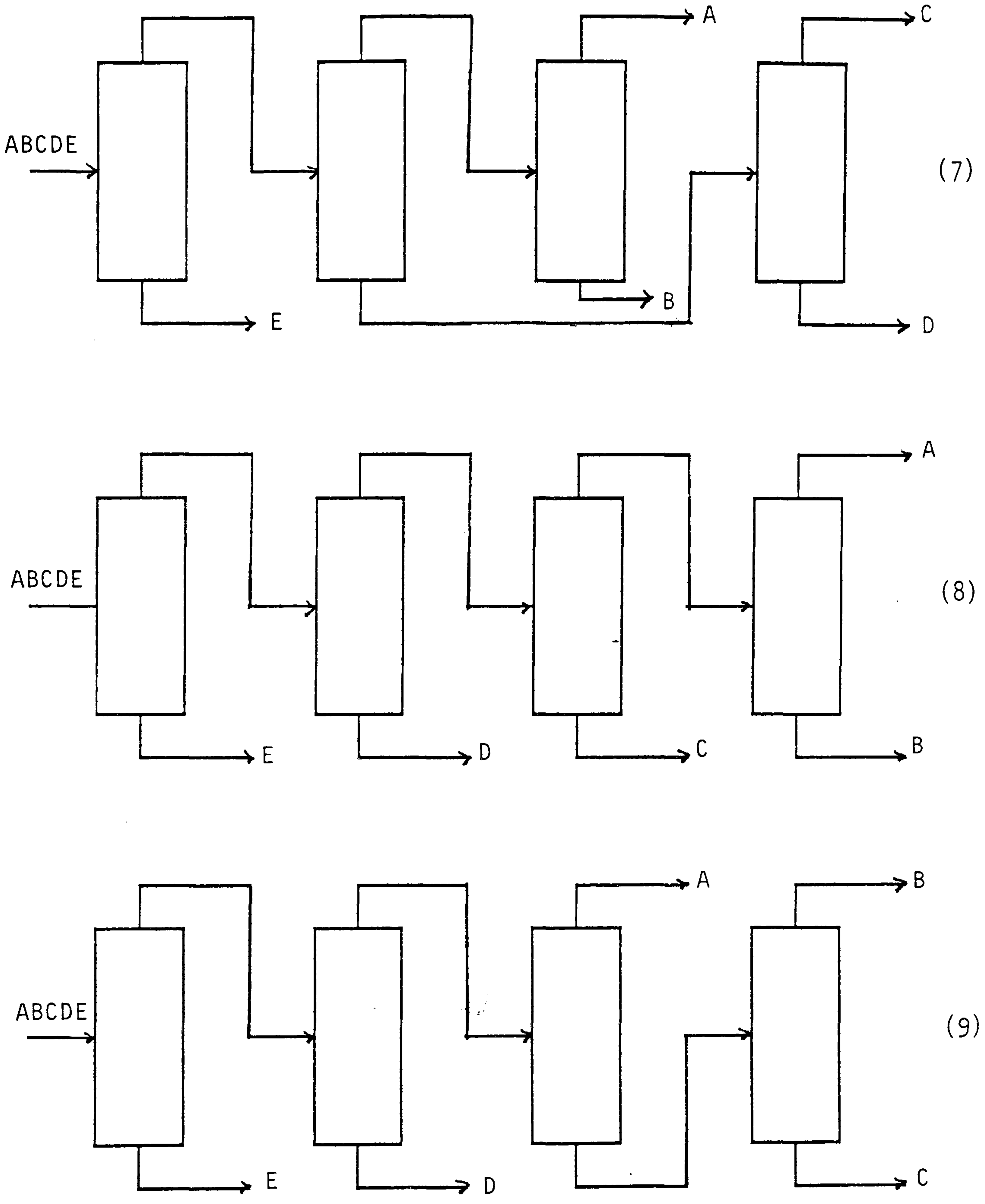


FIG. E1-3 (CONTINUED)

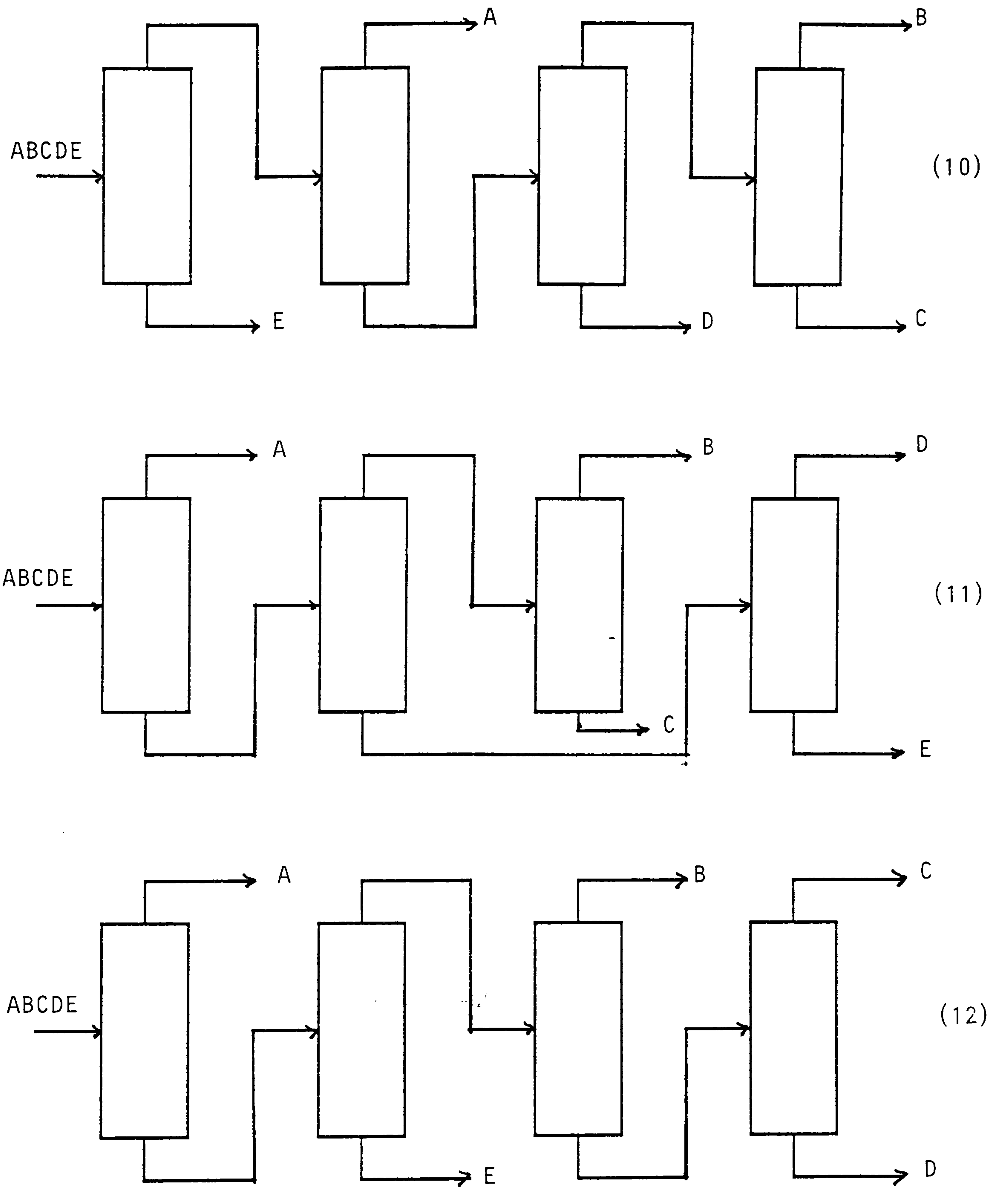


FIG. E1-3 (CONTINUED)

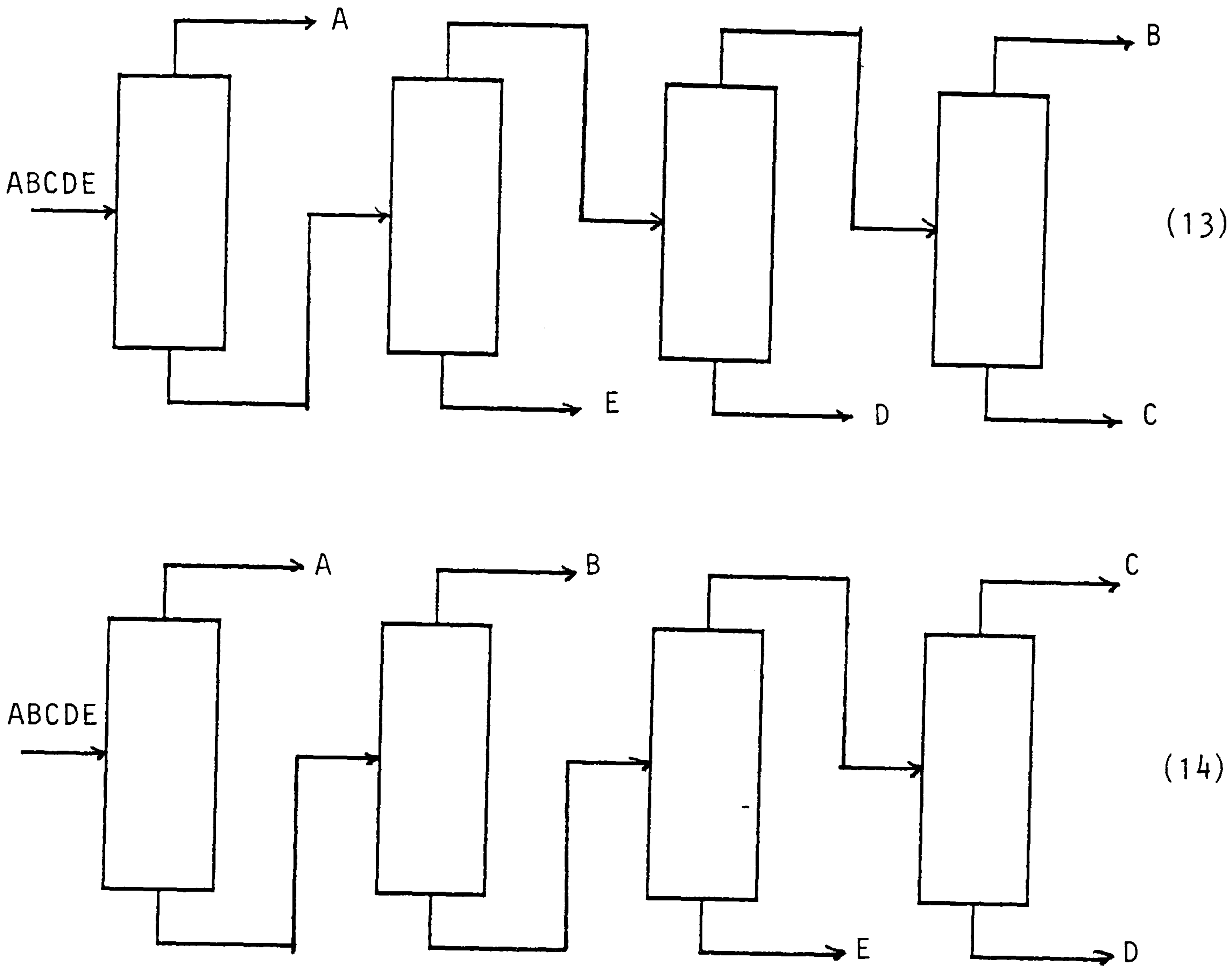


FIG. E1-3 (CONTINUED)

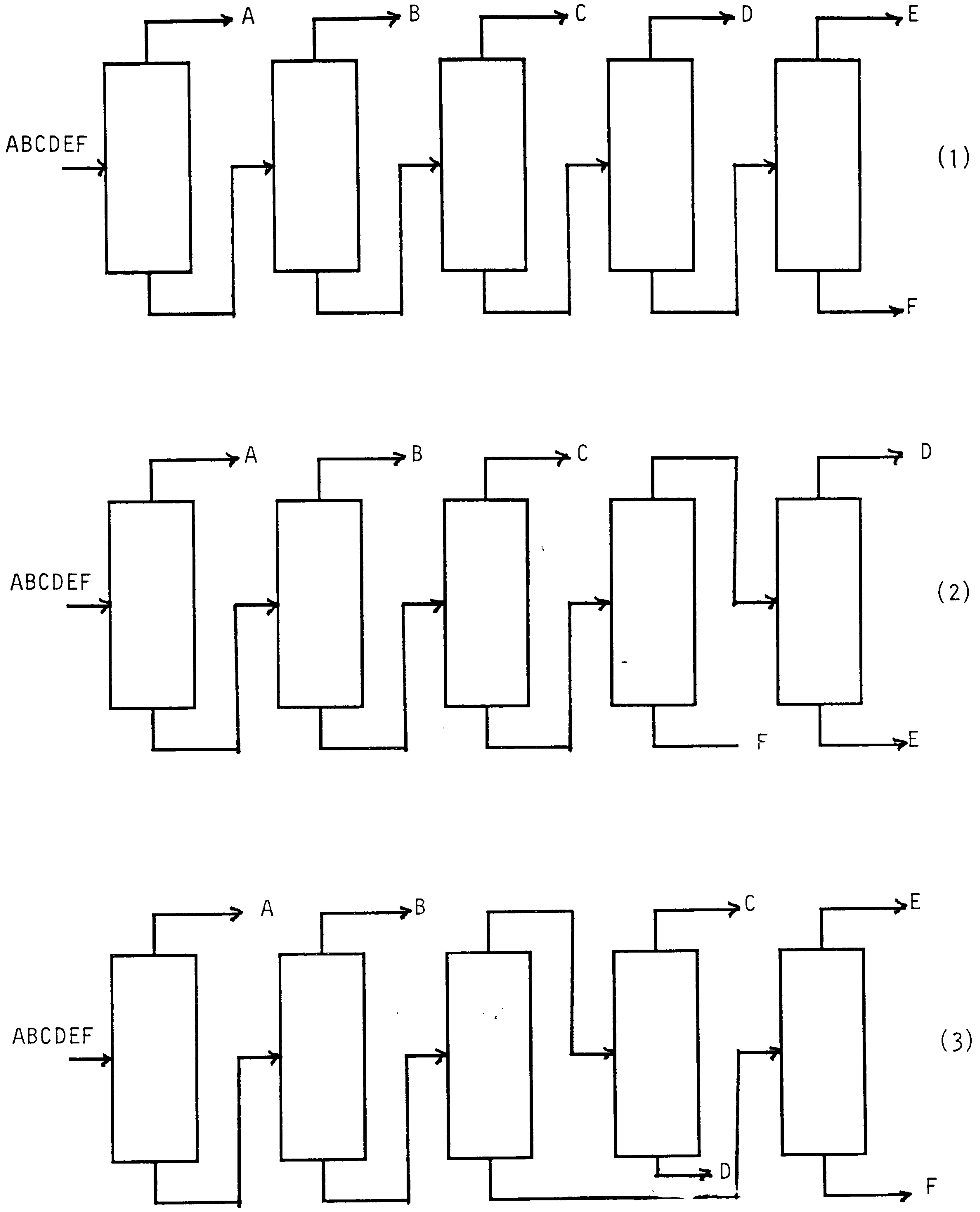
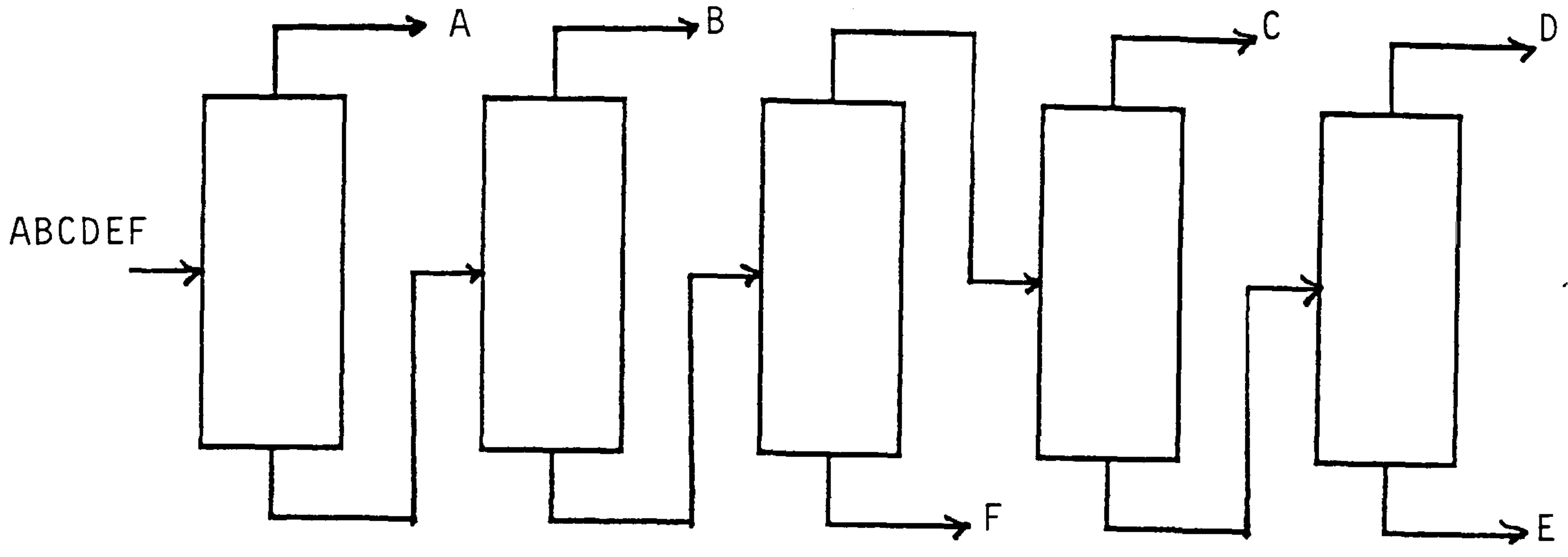
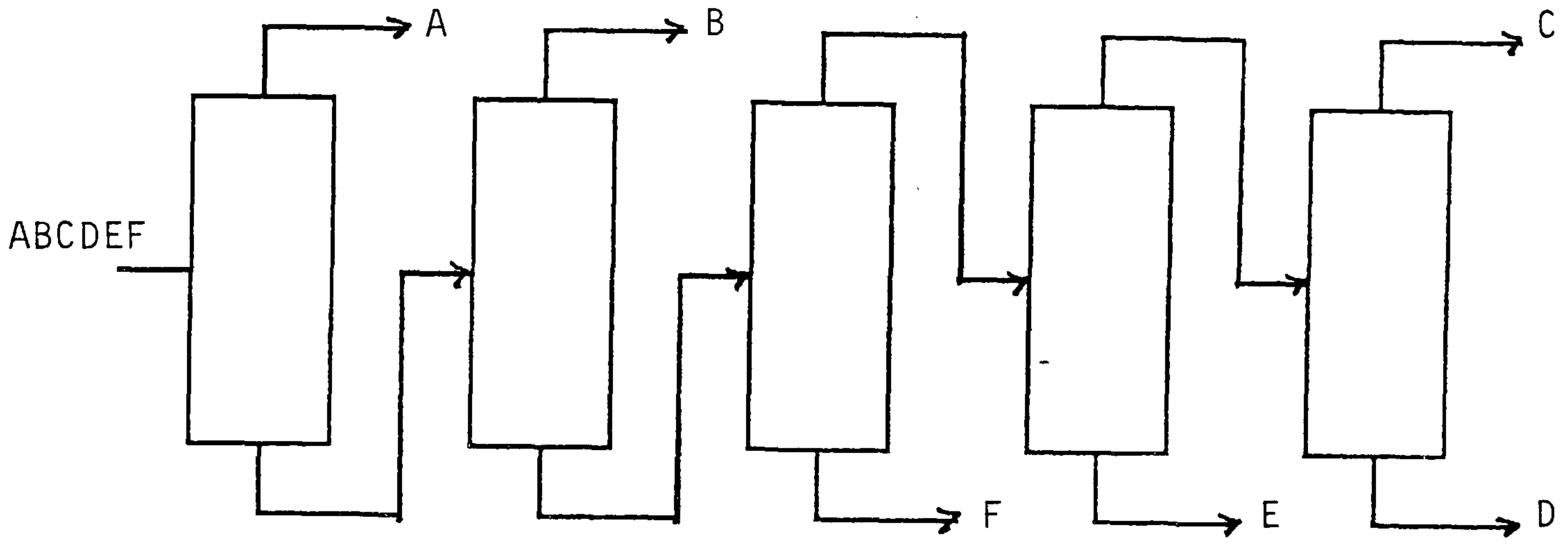


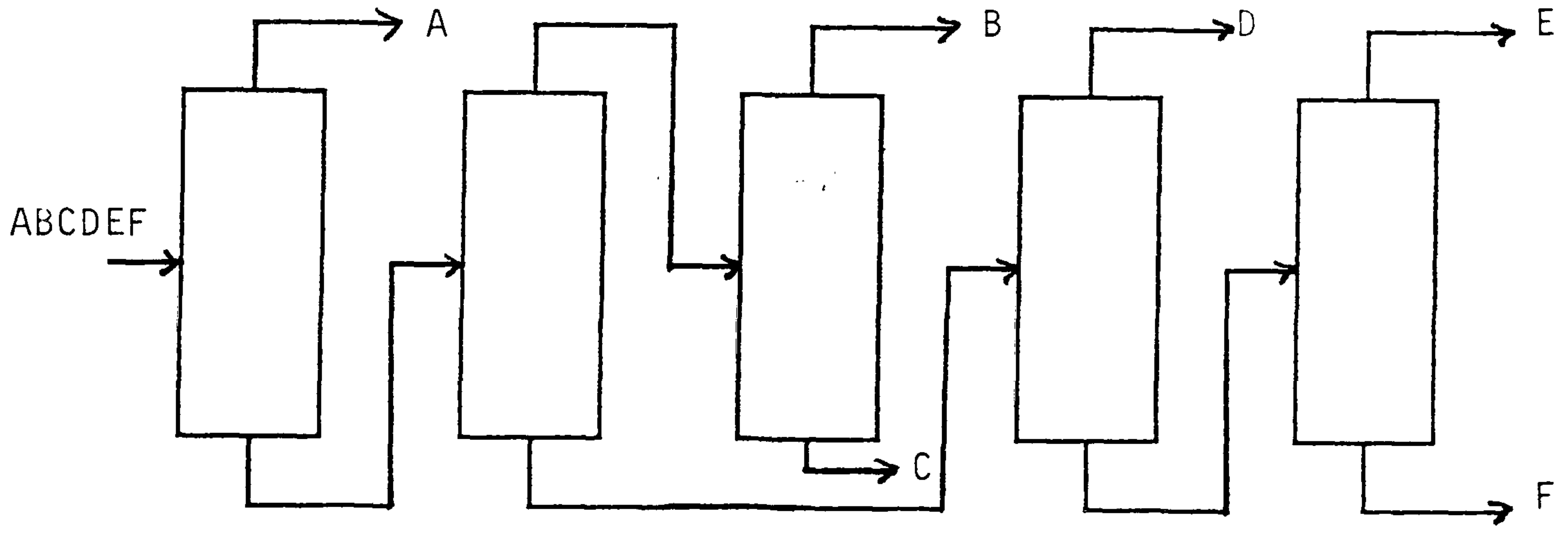
FIG. E1-4 POSSIBLE NUMBER OF SEQUENCES FOR A SIX-COMPONENT MIXTURE.



(4)



(5)



(6)

FIG. E1-4 (CONTINUED)

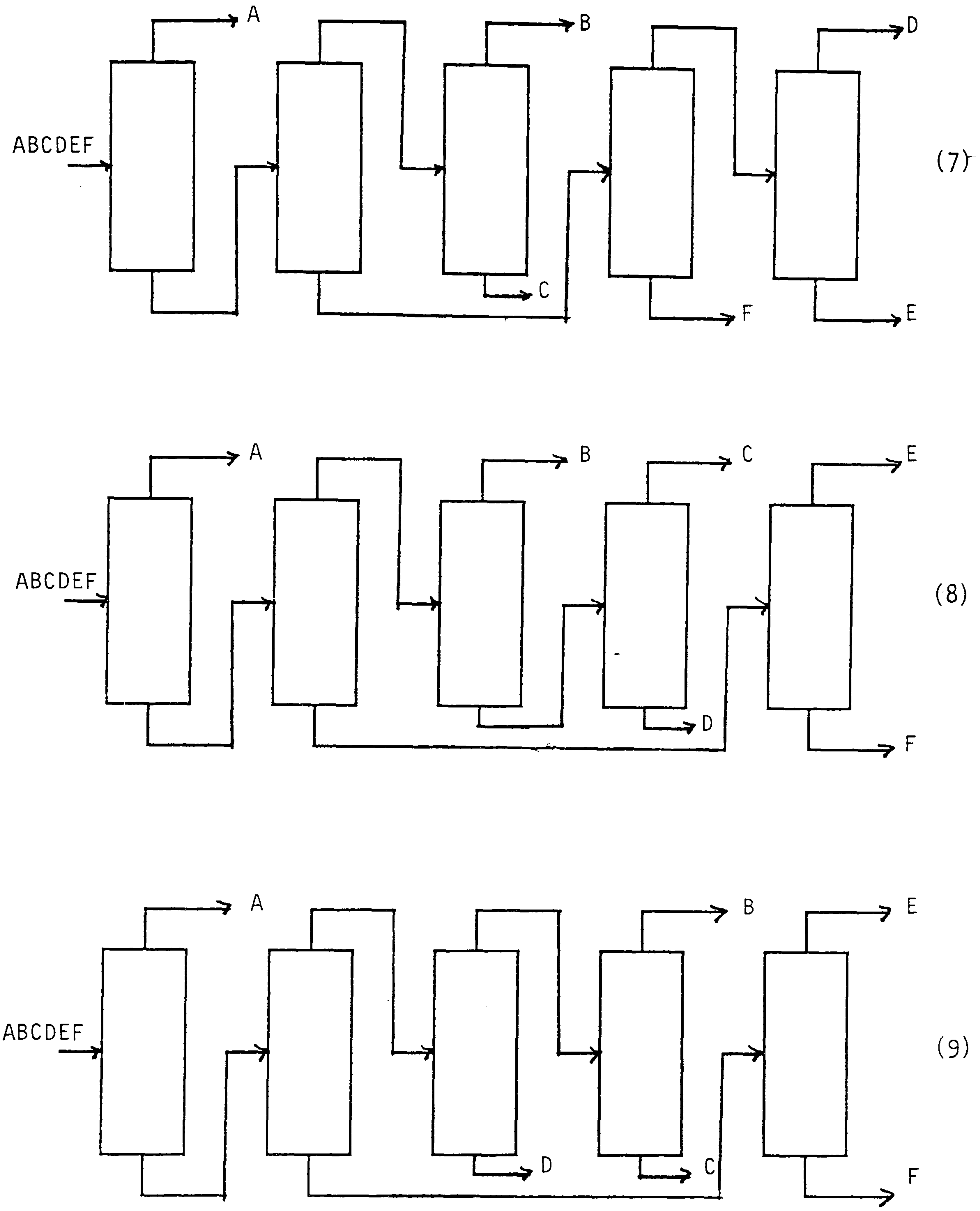
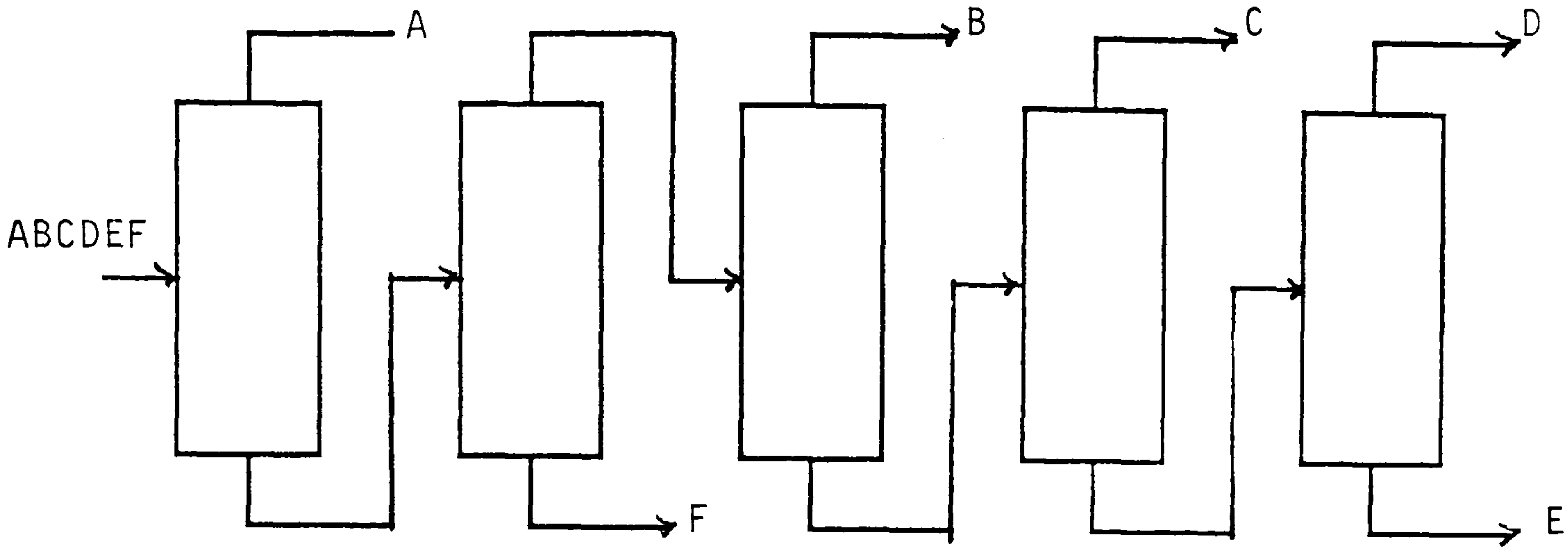


FIG. E1-4 (CONTINUED)



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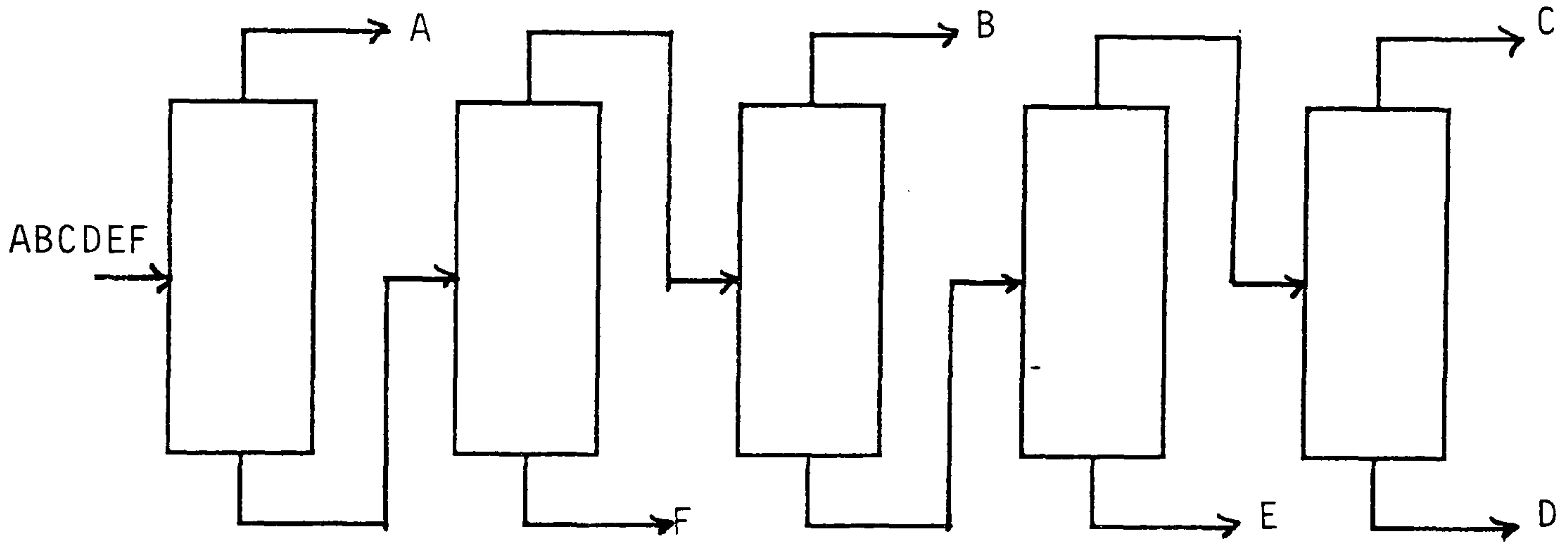

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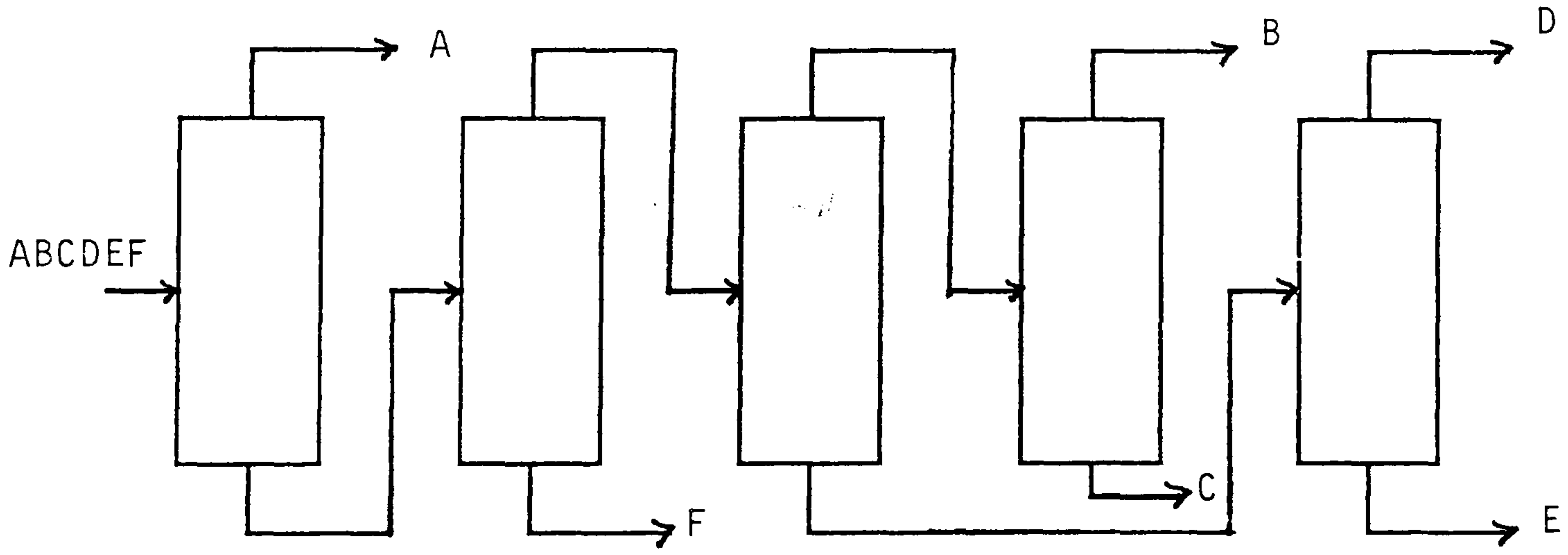
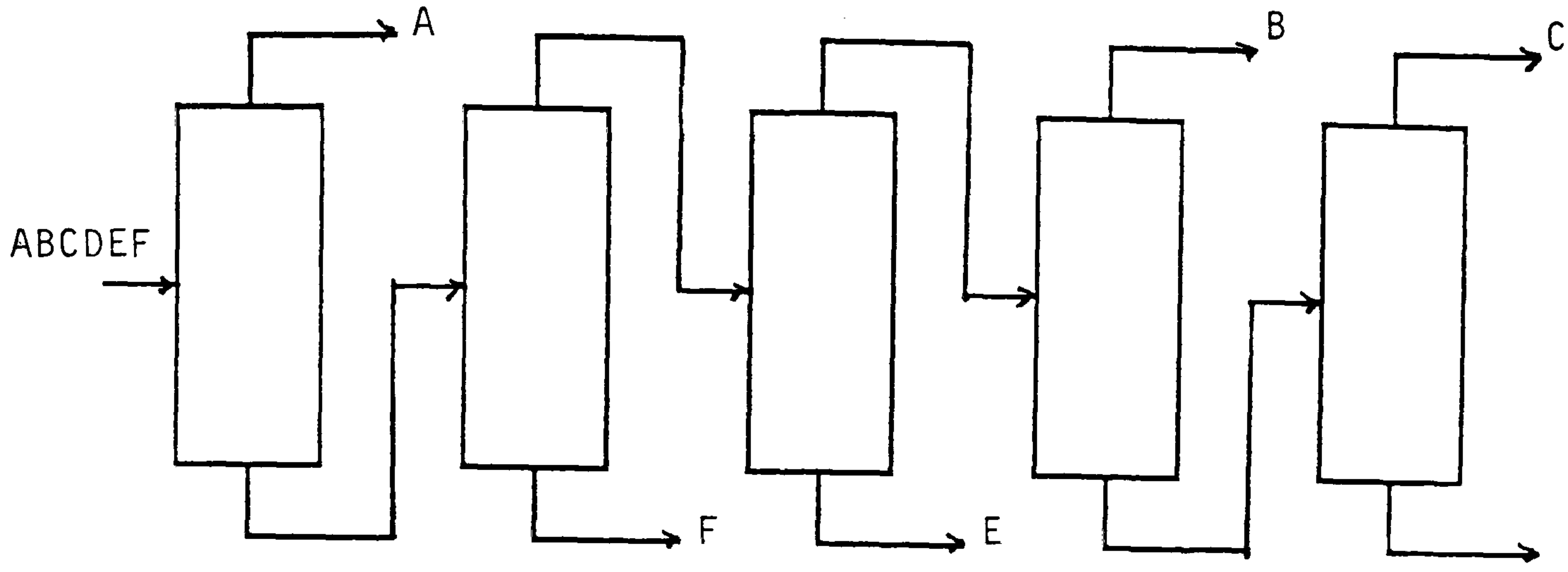
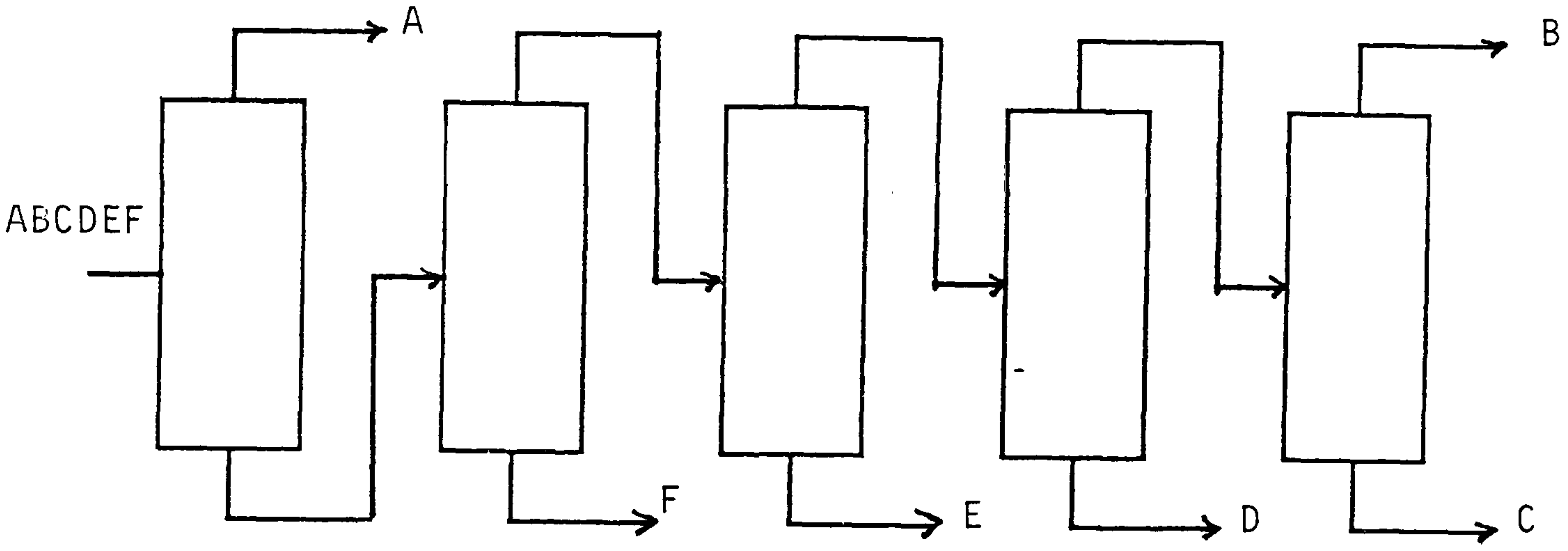


(12)

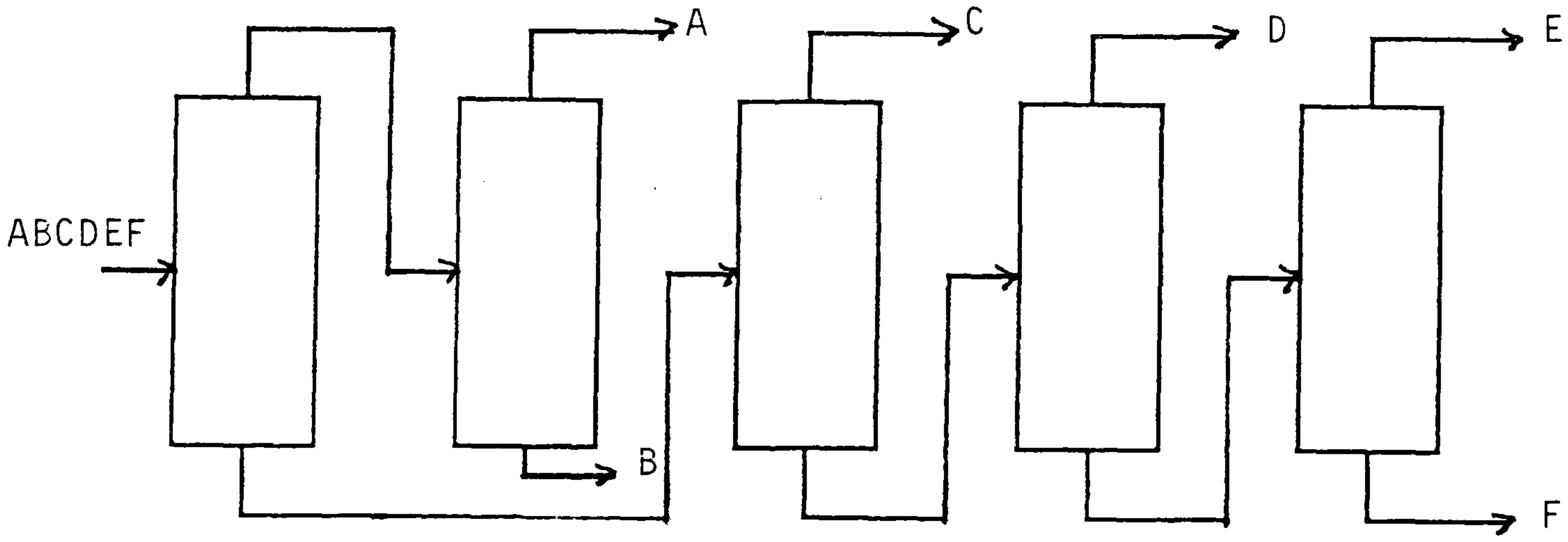
FIG. E1-4 (CONTINUED)



(13)

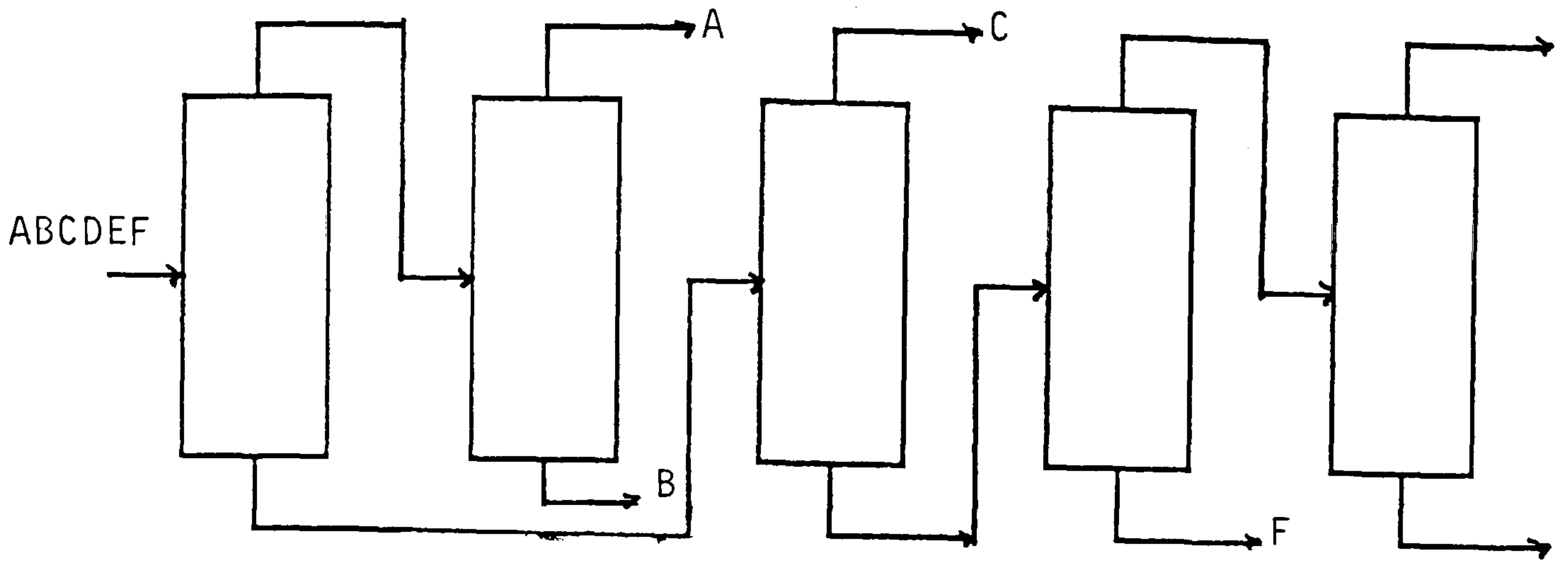


(14)

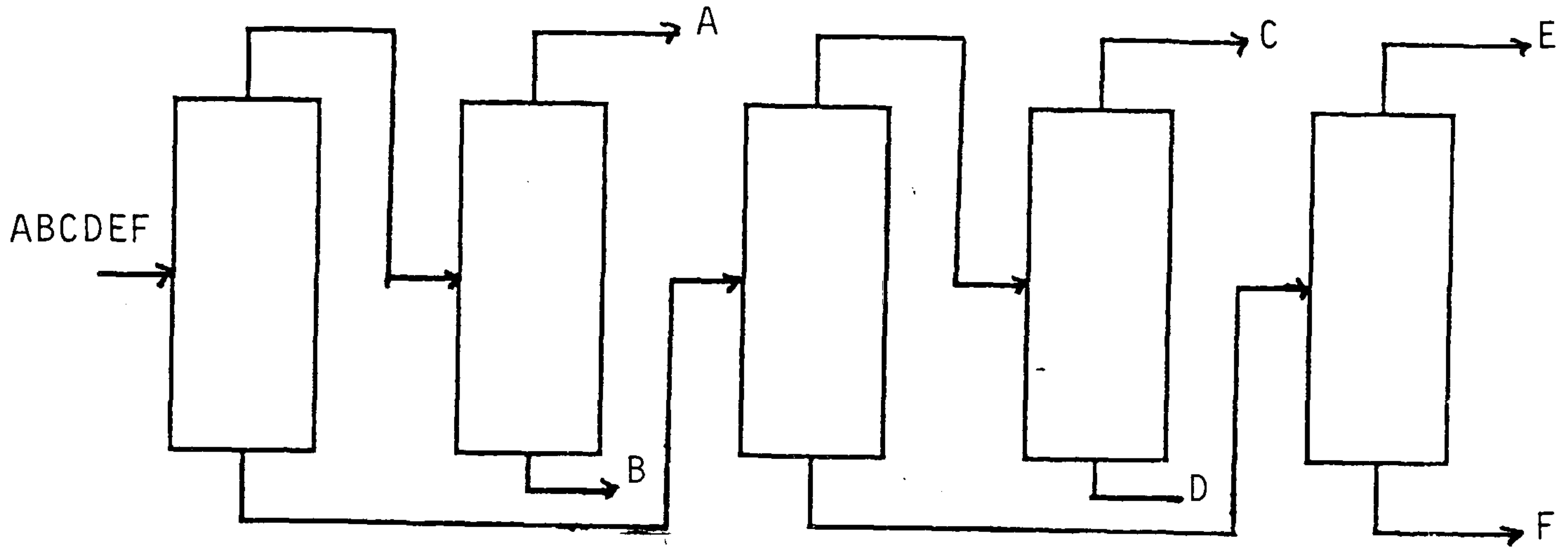


(15)

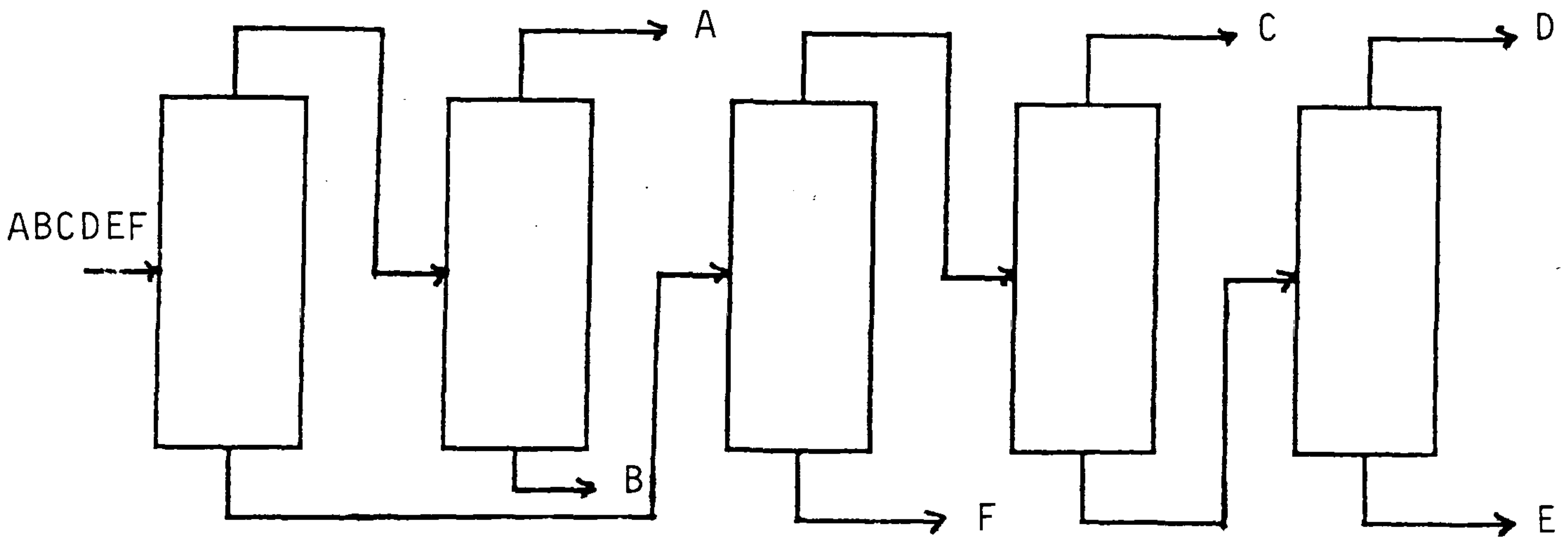
FIG. E1-4 (CONTINUED



(16)

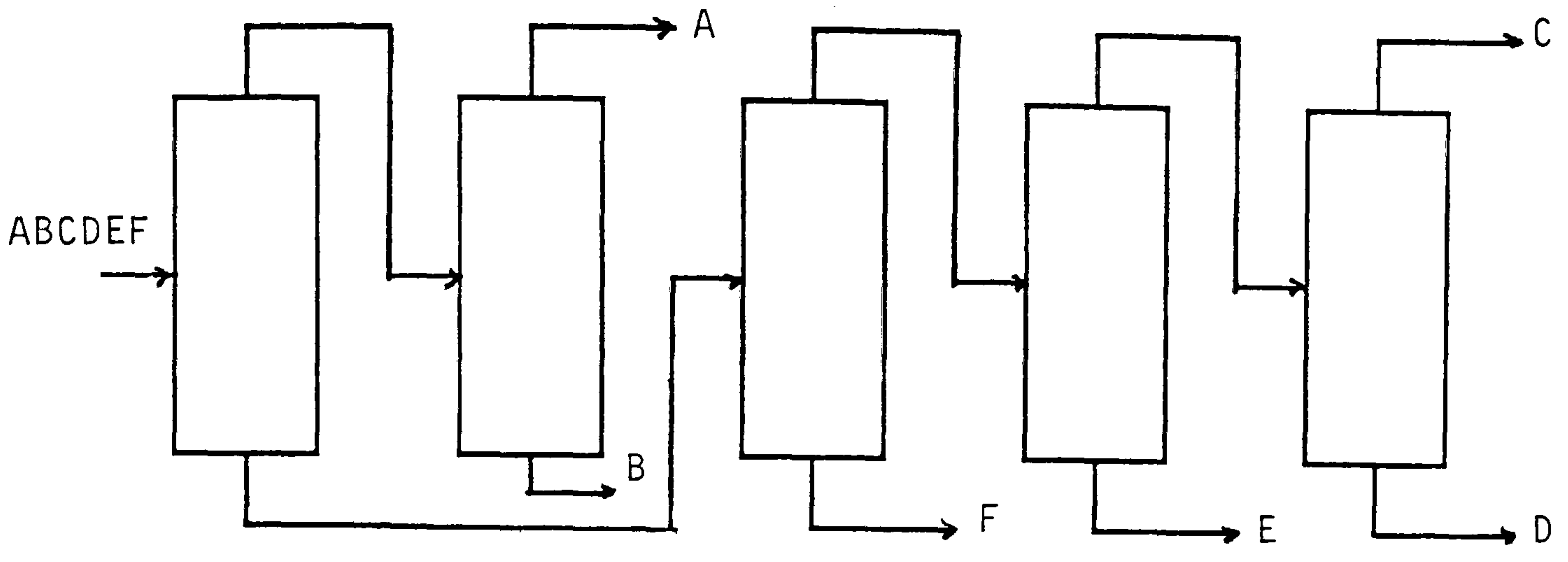


(17)

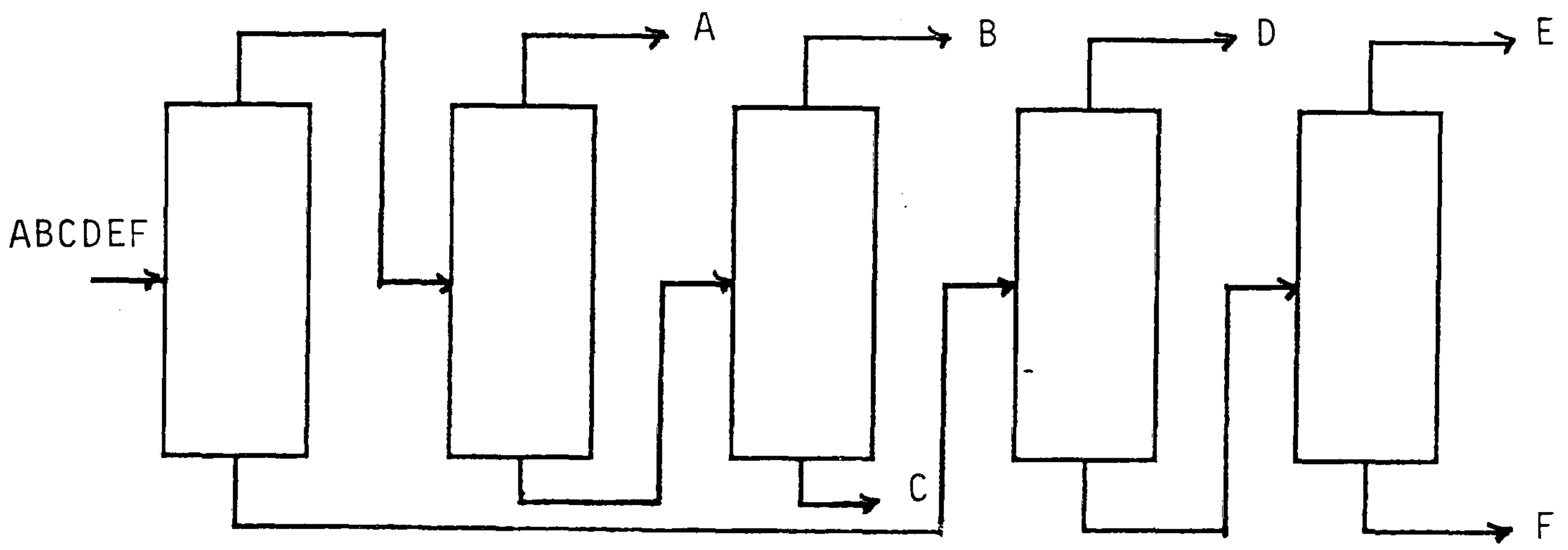


(18)

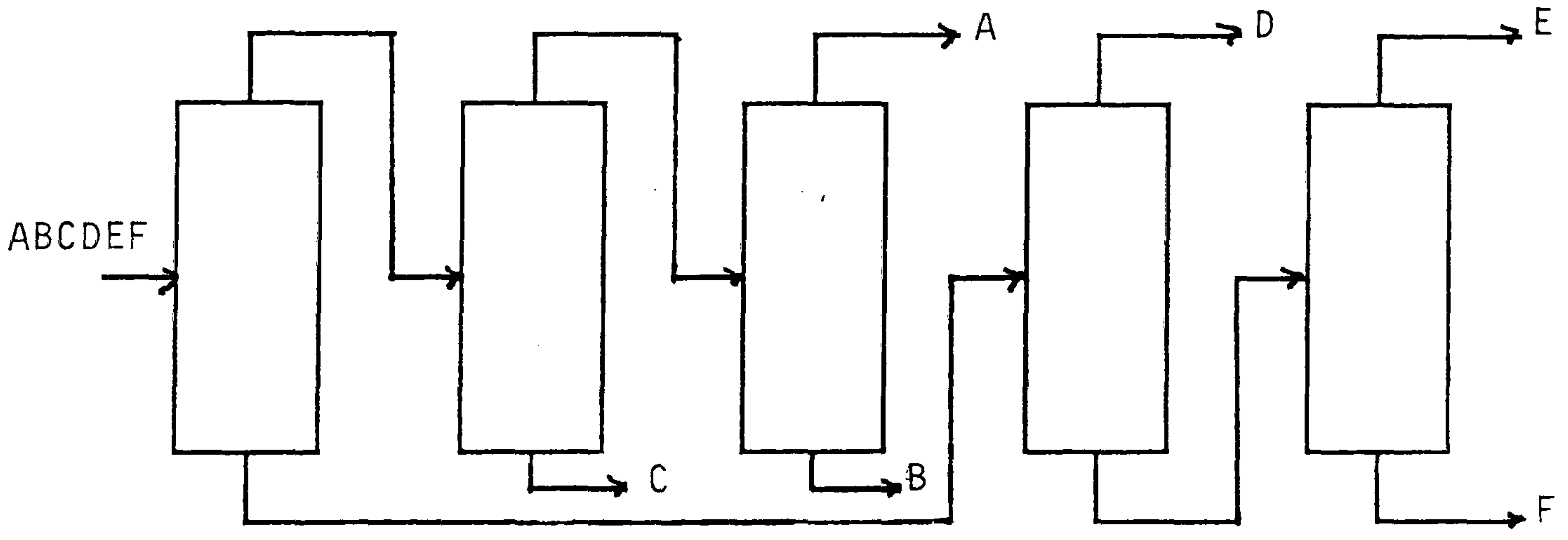
FIG. E1-4 (CONTINUED)



(19)

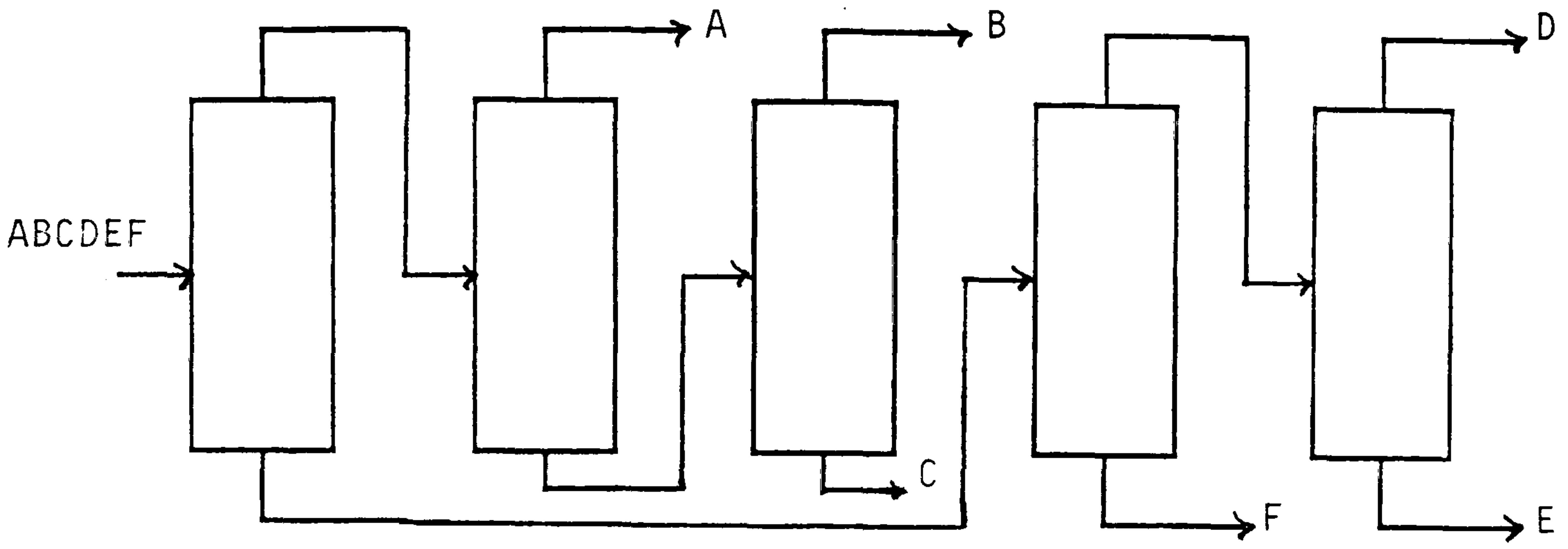


(20)

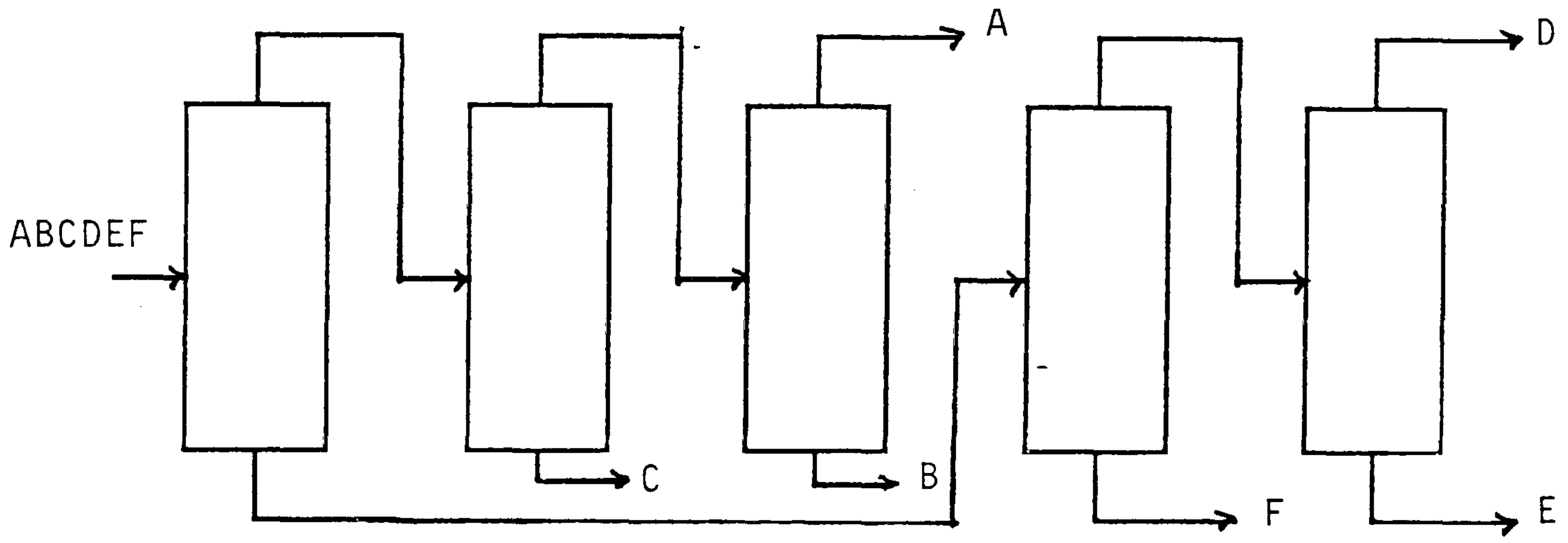


(21)

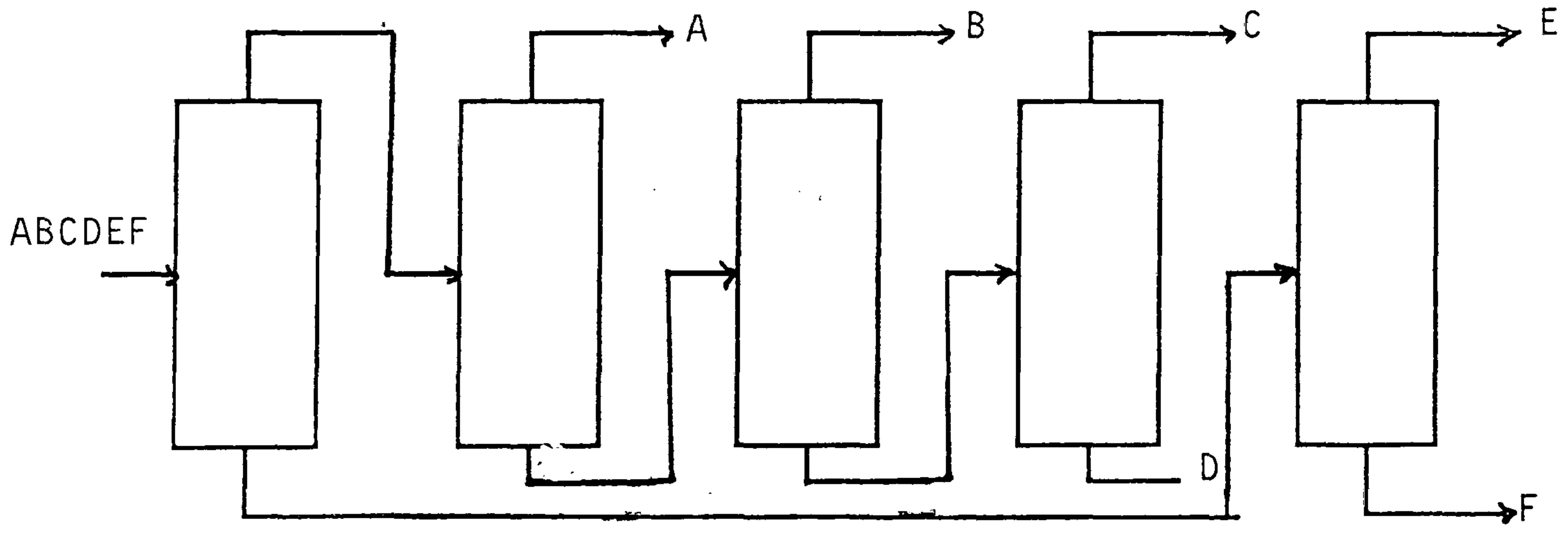
FIG. E1-4 (CONTINUED)



(22)

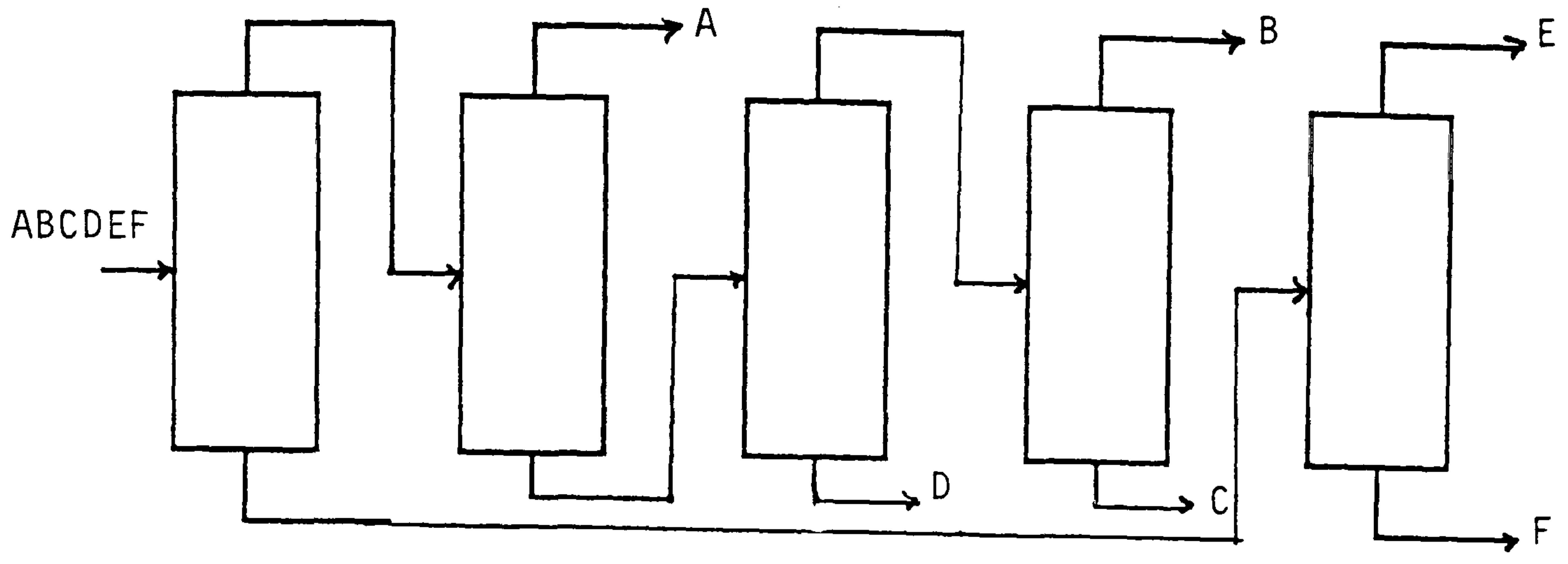


(23)

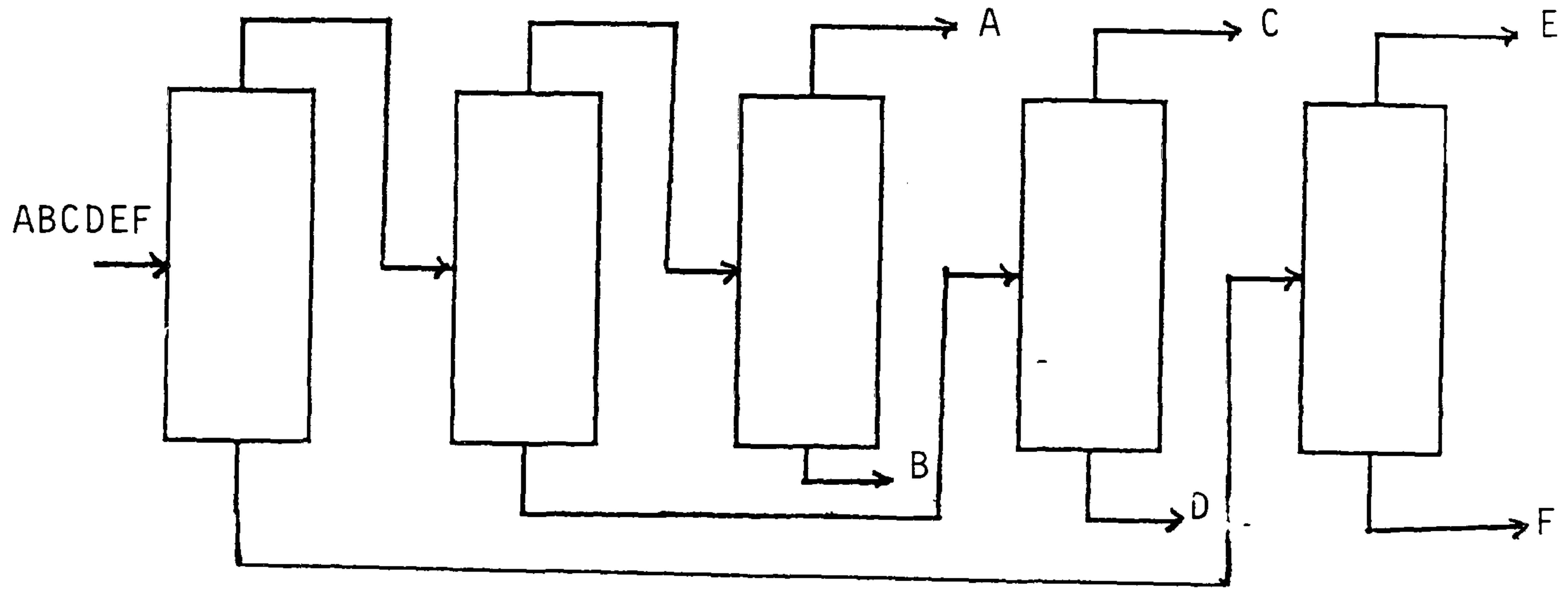


(24)

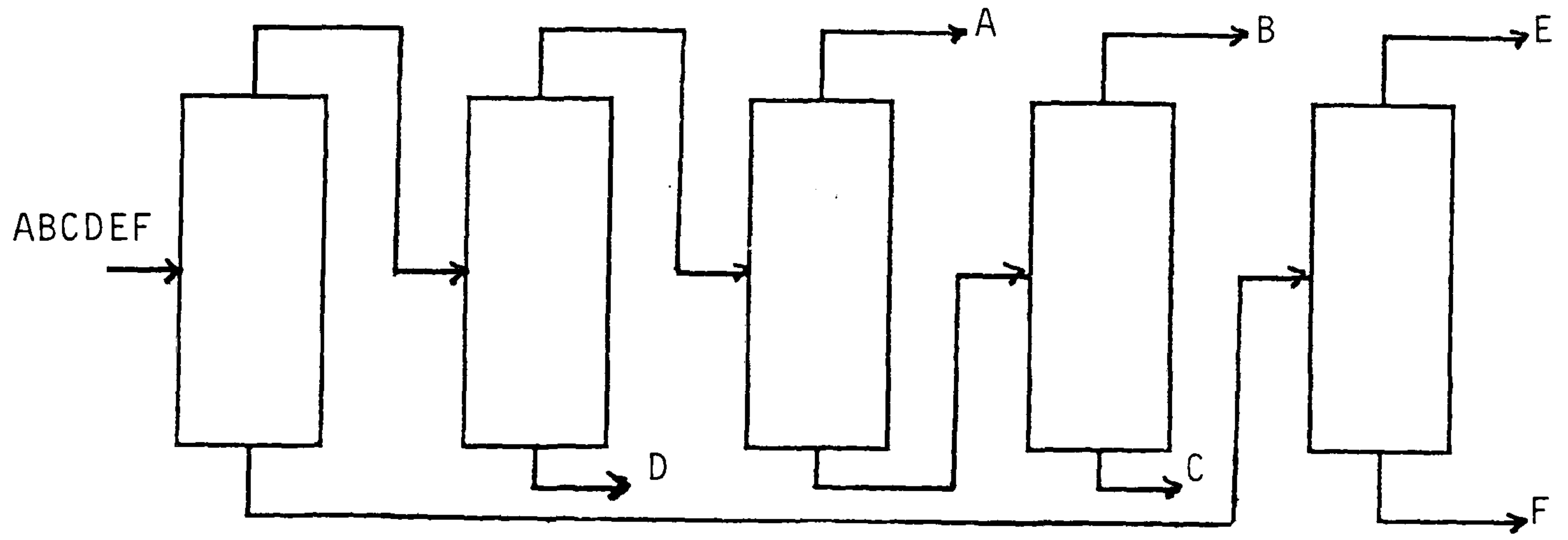
FIG. E1-4 (CONTINUED)



(25)

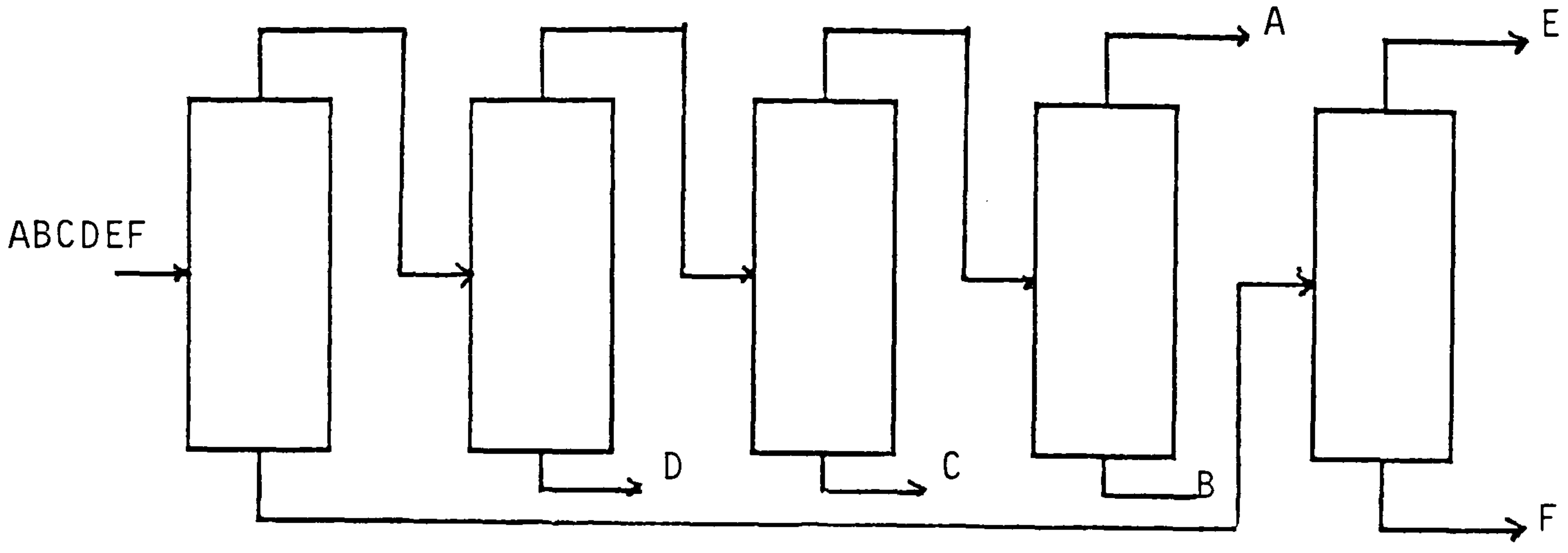


(26)

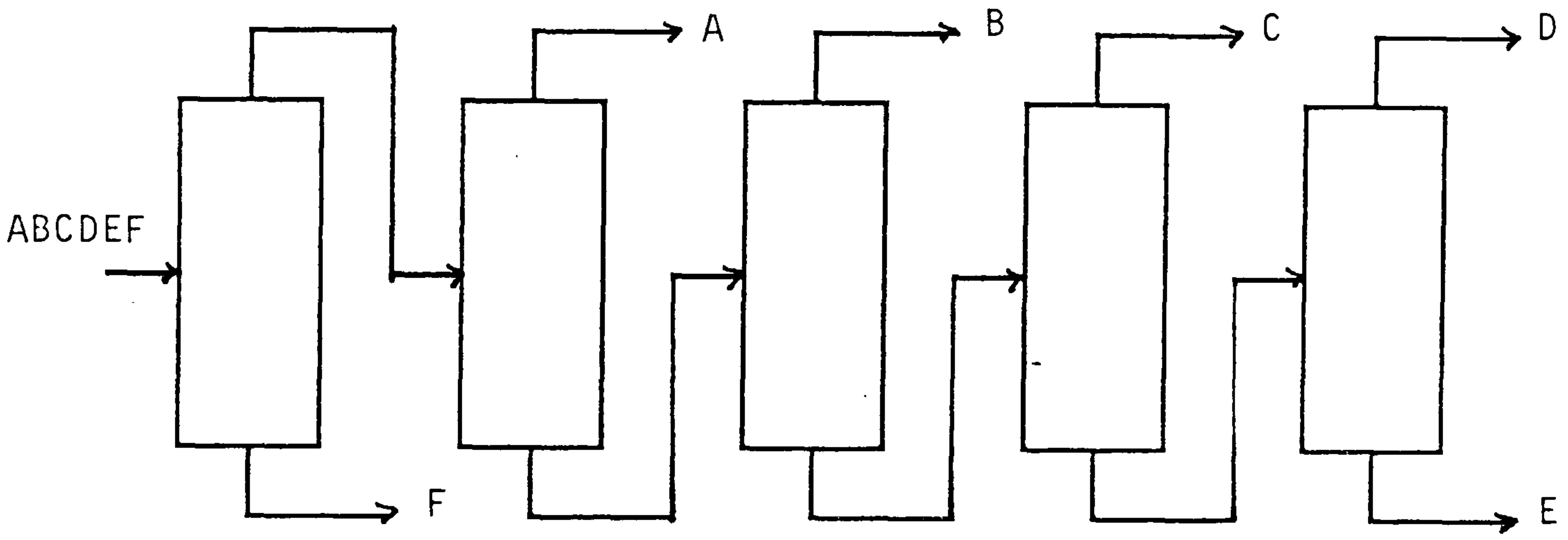


(27)

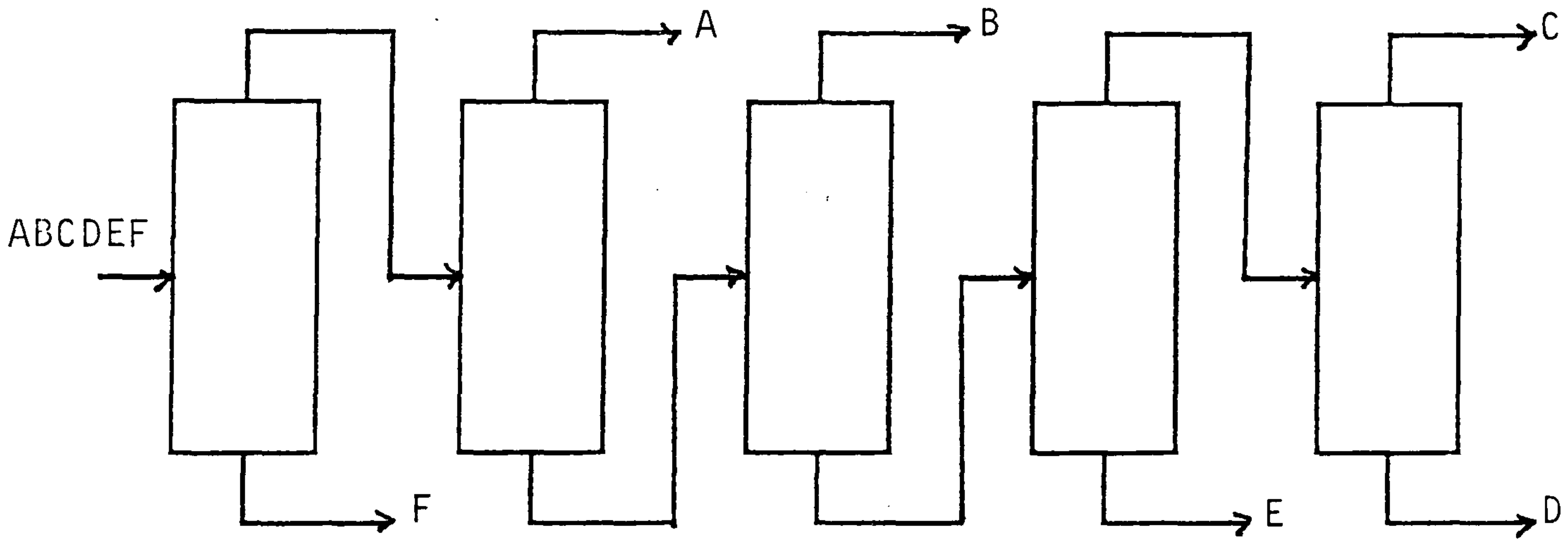
FIG. E1-4 (CONTINUED)



(28)



(29)



(30)

FIG. E1-4 (CONTINUED)

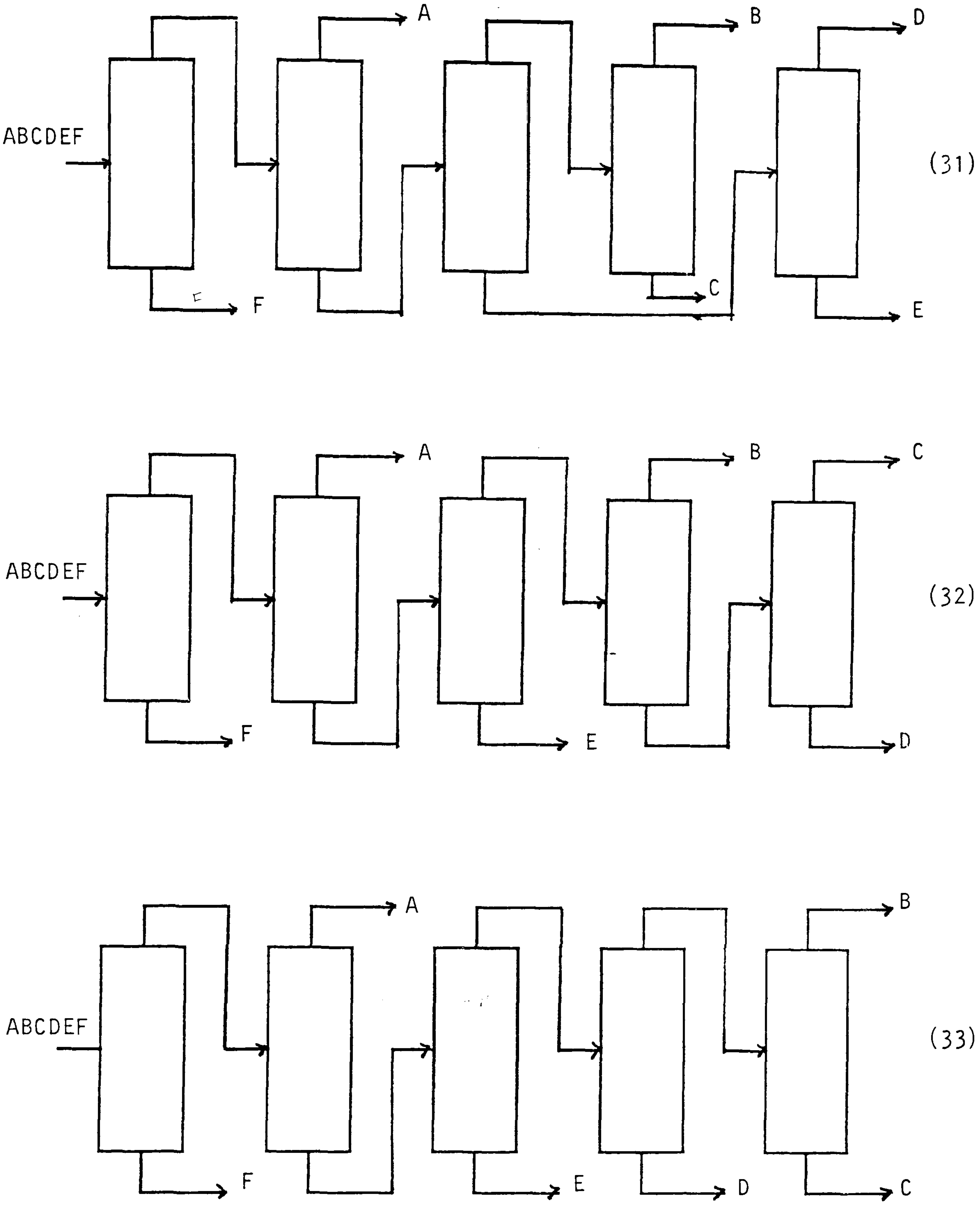
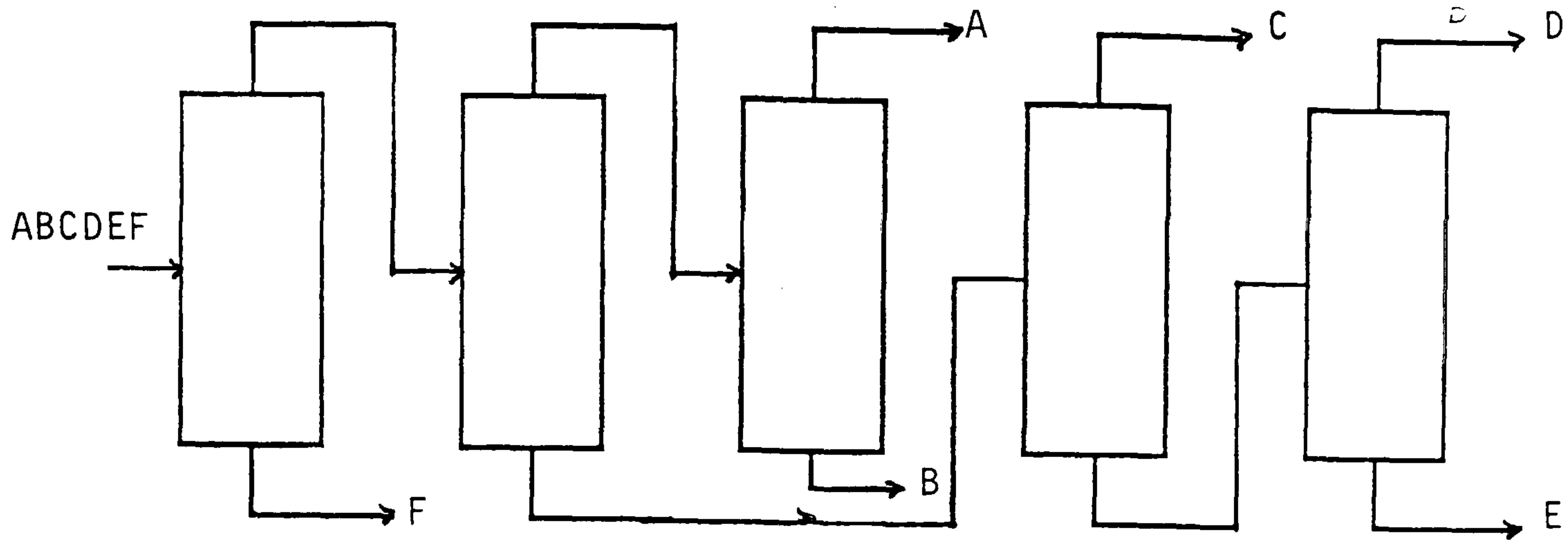
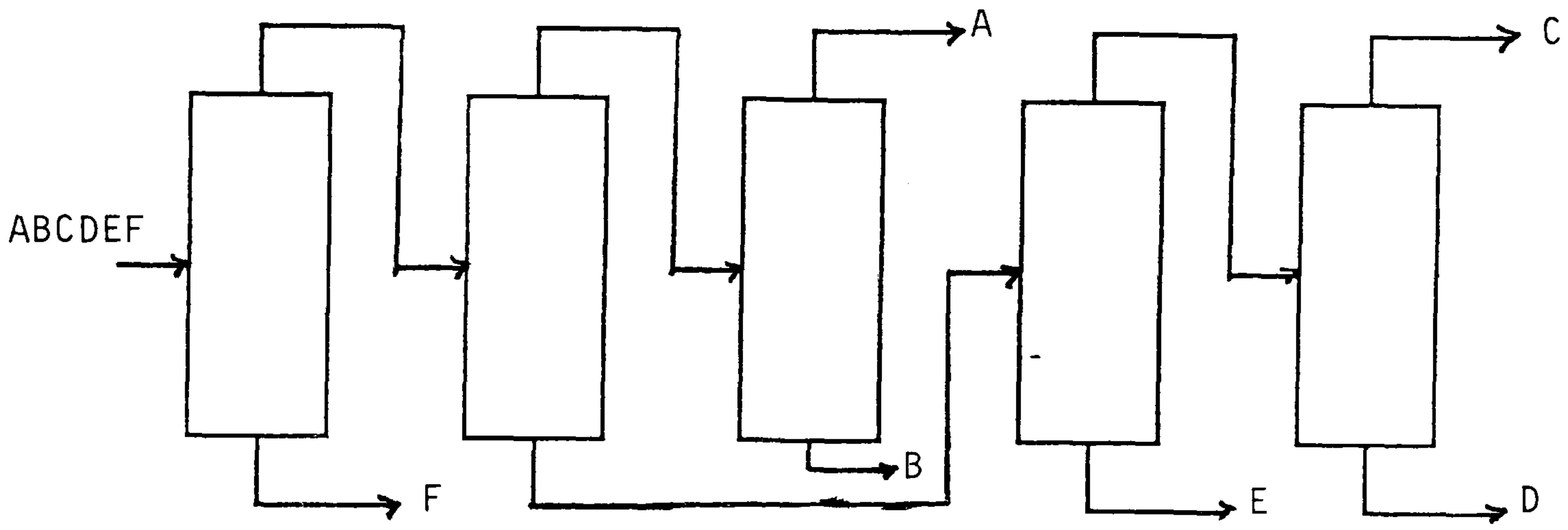


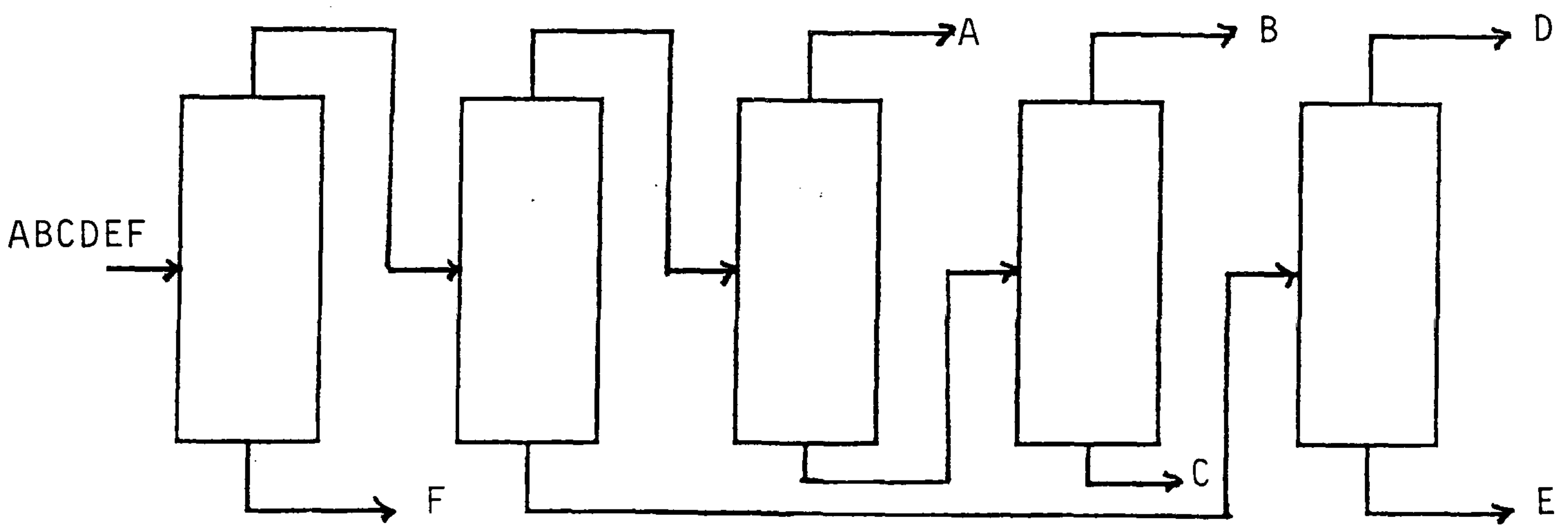
FIG. E1-4 (CONTINUED)



(34)

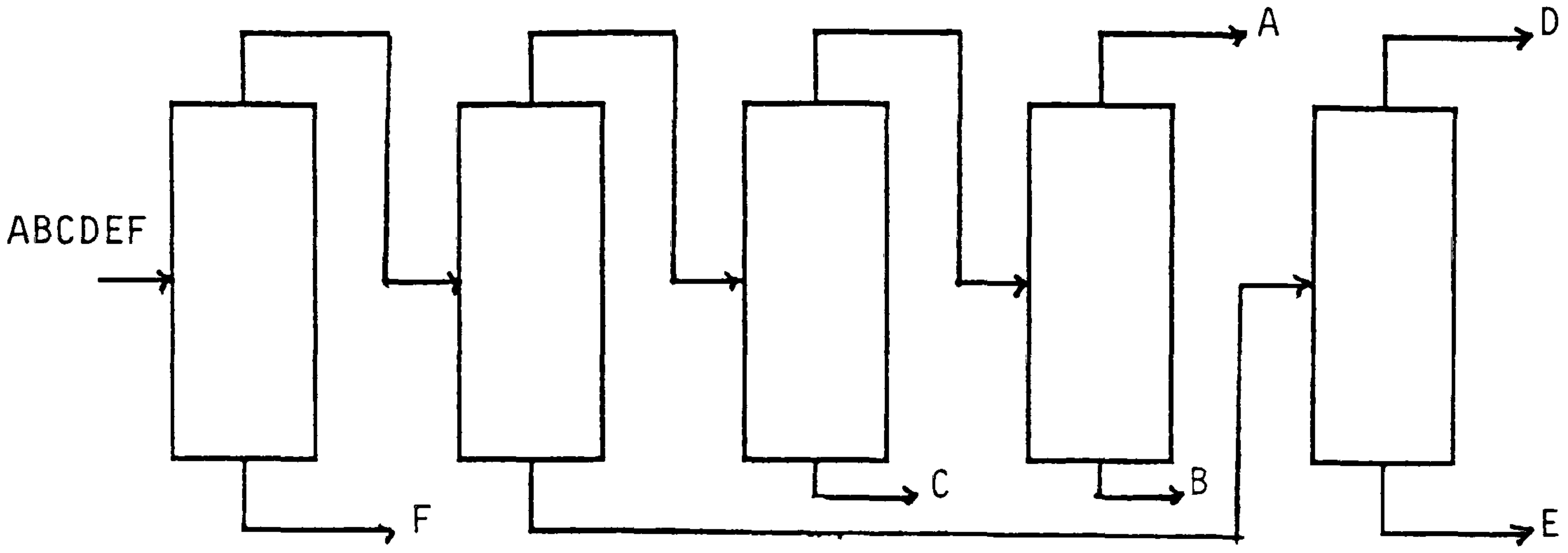


(35)

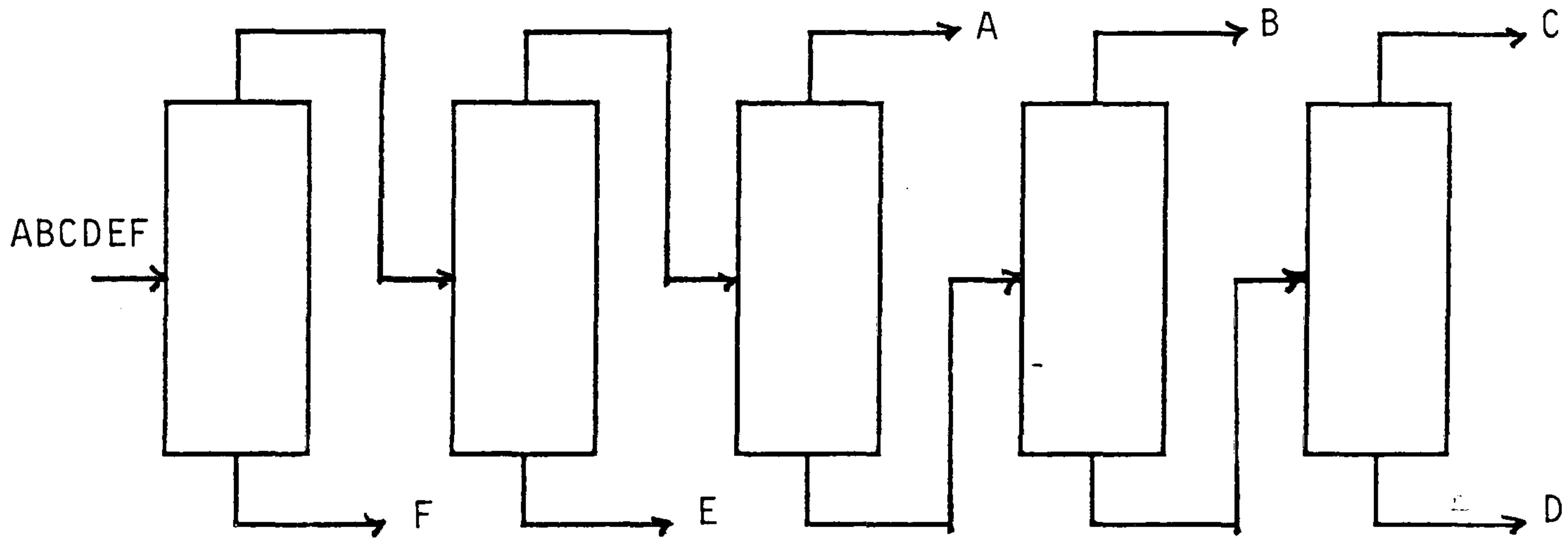


(36)

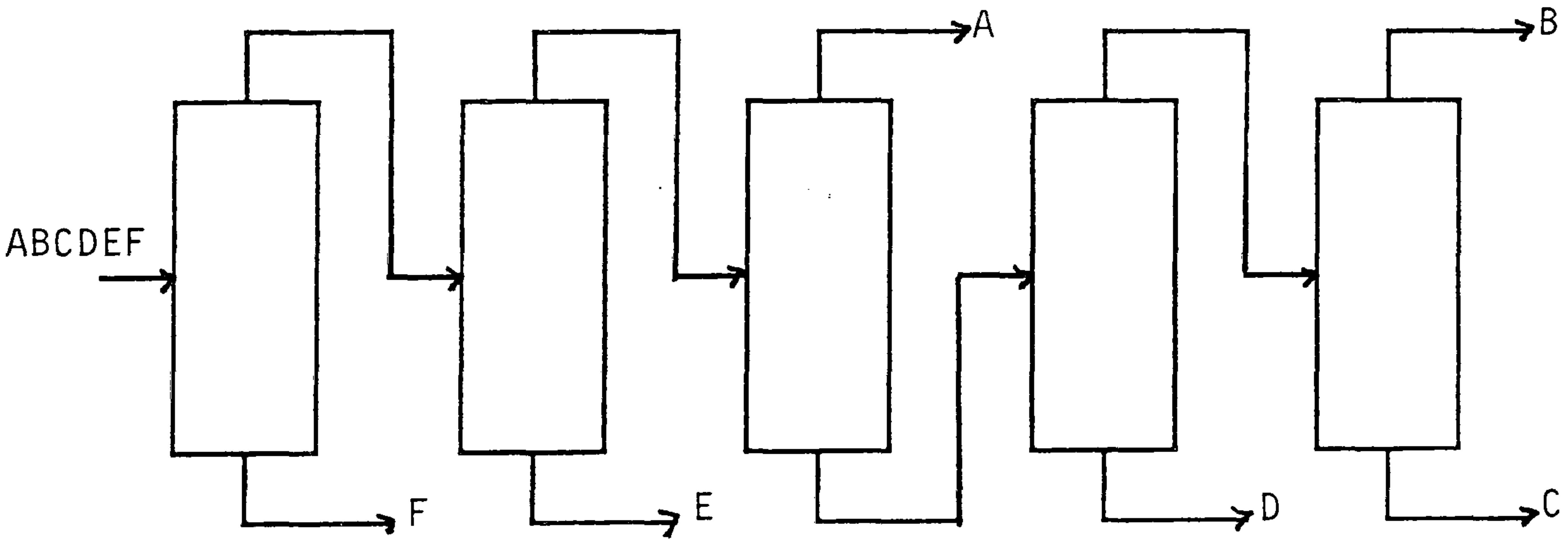
FIG. E1-4 (CONTINUED)



(37)

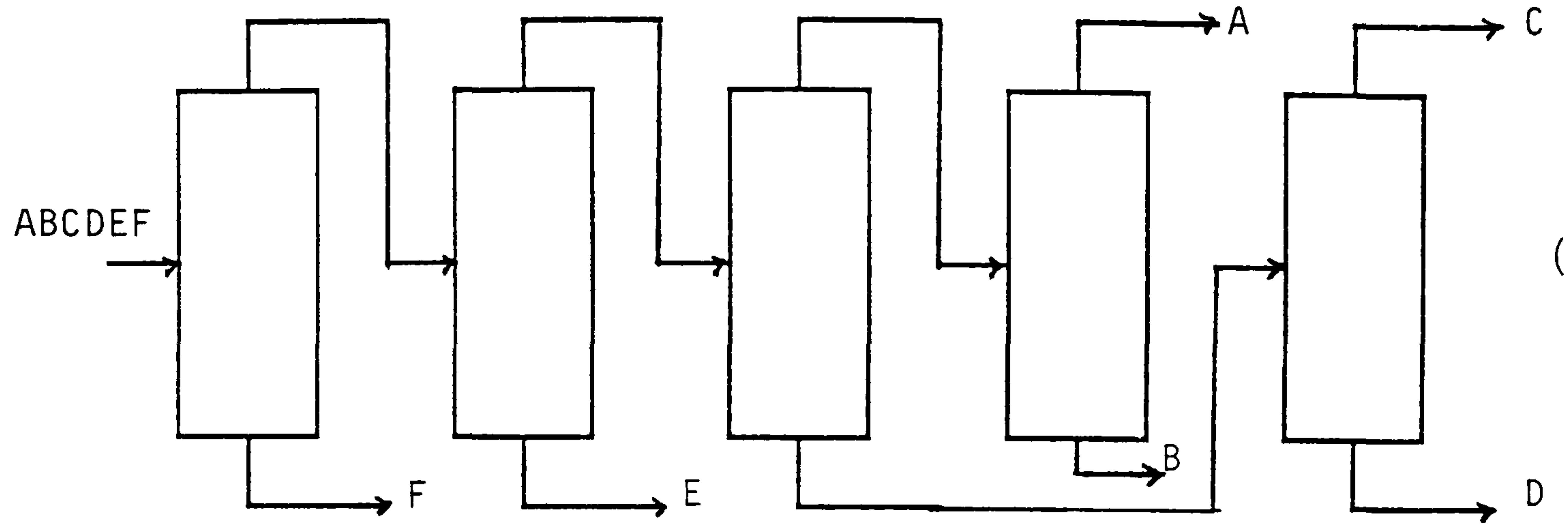


(38)

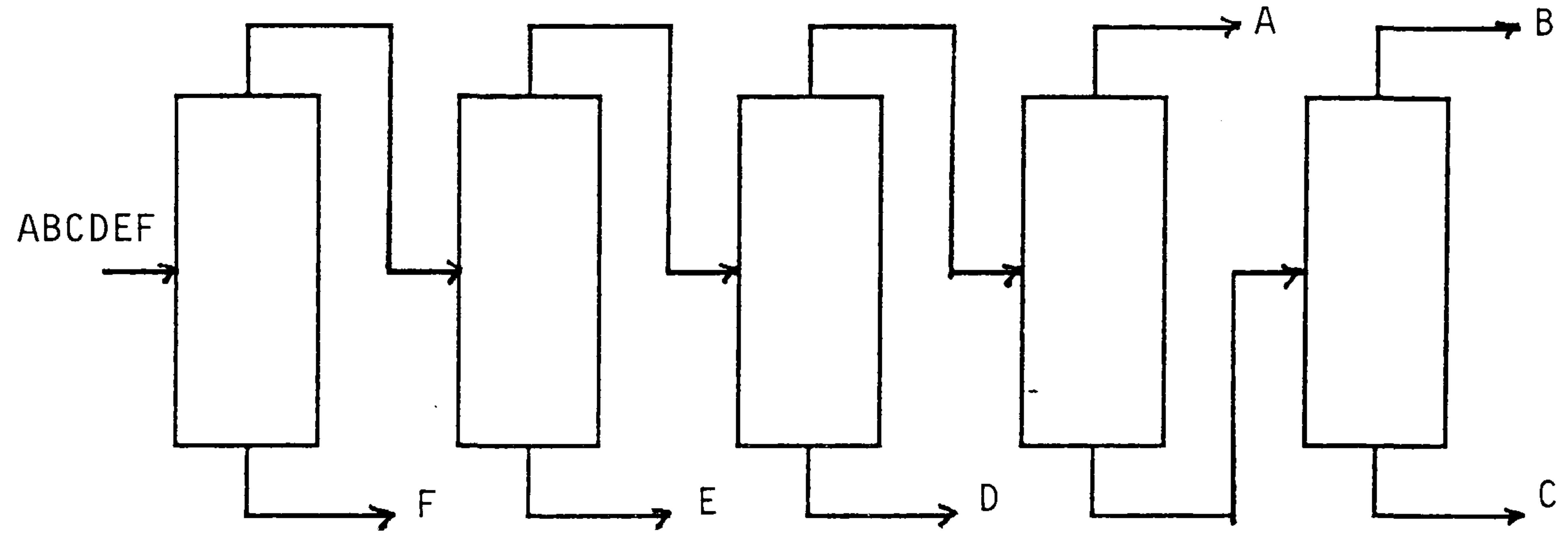


(39)

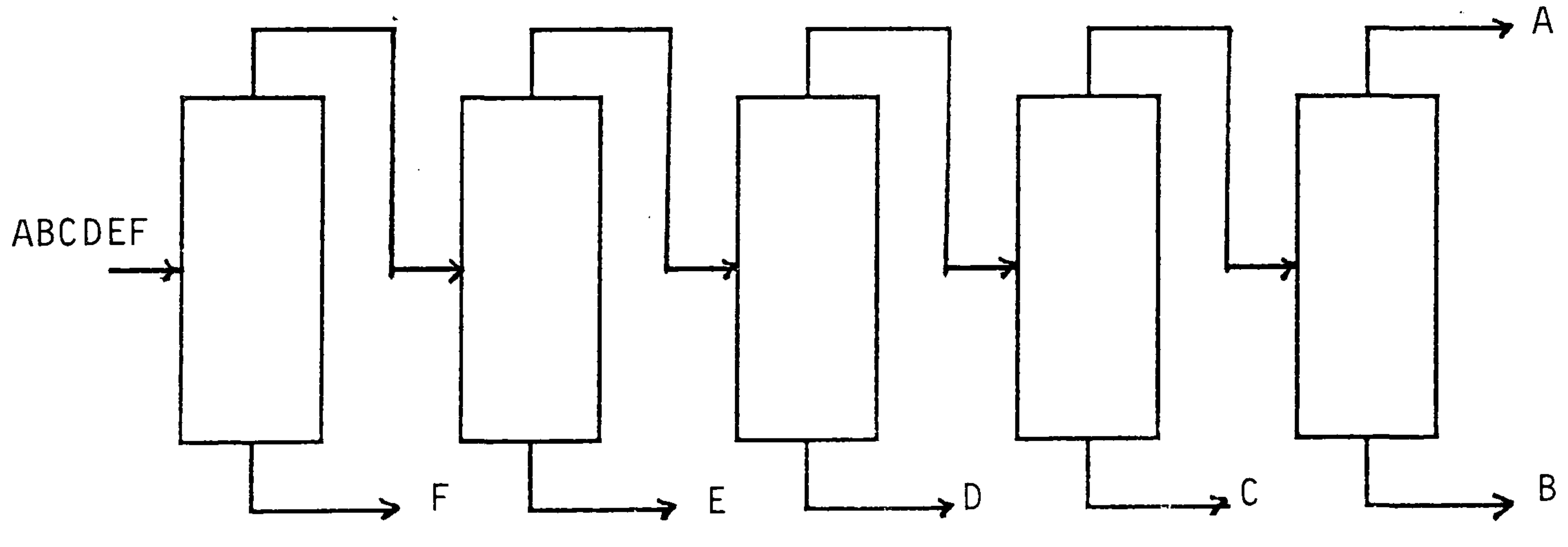
FIG. E1-4 (CONTINUED)



(40)



(41)



(42)

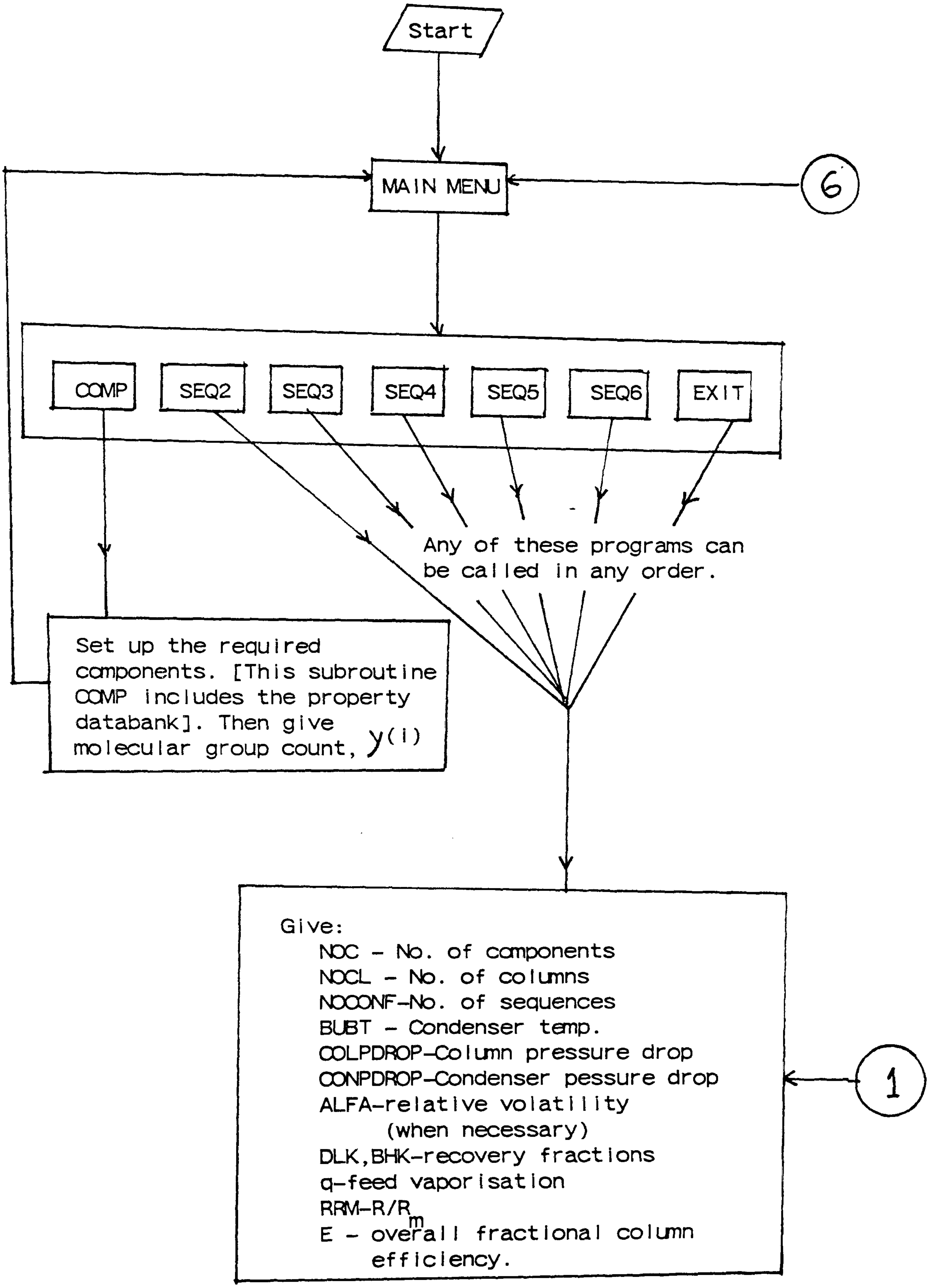
FIG. E1-4 (CONTINUED)

APPENDIX F

FLOW CHARTS OF THE COMPUTER PACKAGE.

The flowcharts given are simplified ; and in each case only major features of the programs (or subprograms) are given. Each of the subprograms called may have so many other sub-subprograms that does one calculation or the other. It is advisable to read the charts in conjuction with chapter Nine for a proper understanding.

F-1: MASTER PROGRAM "MAIN"

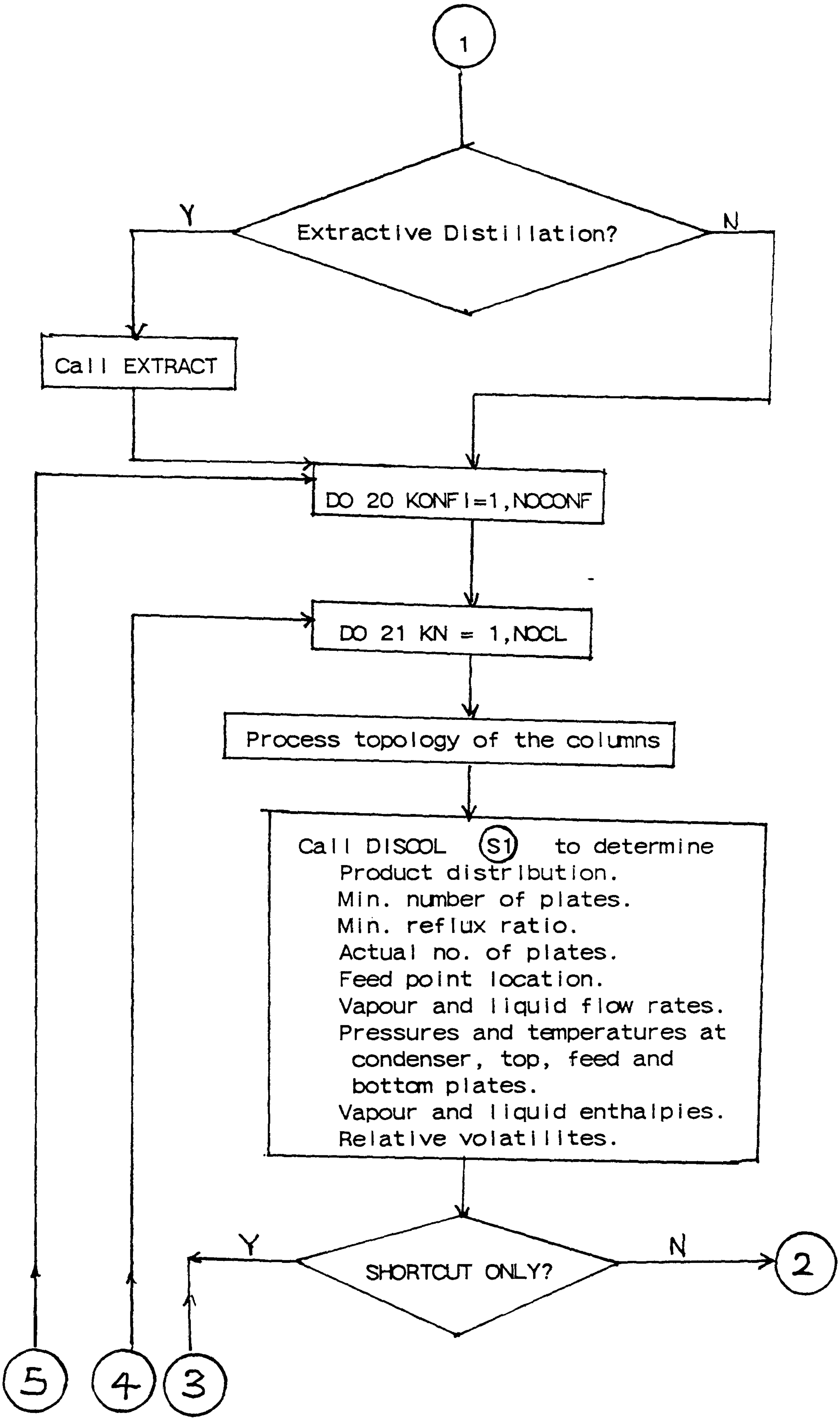


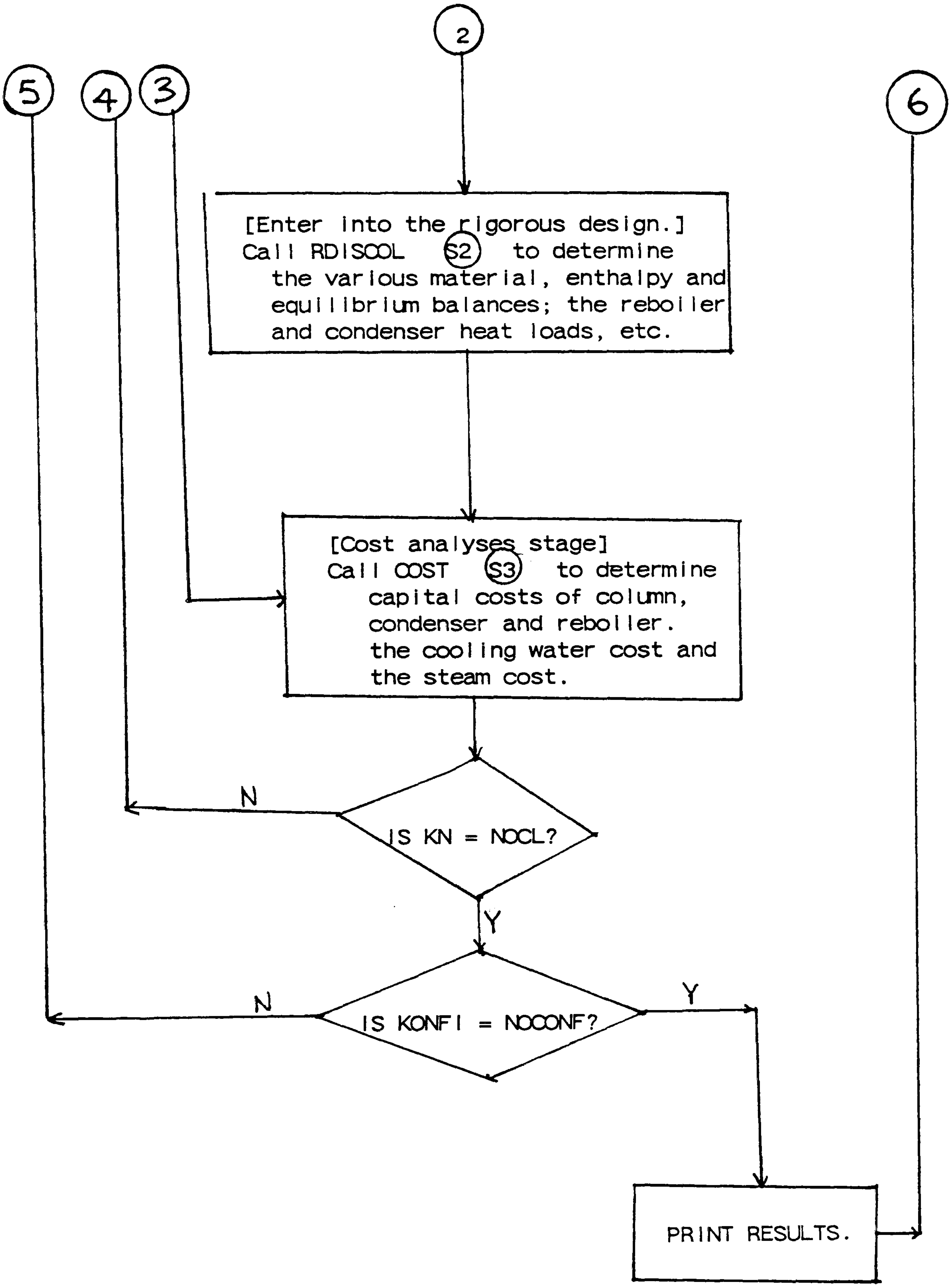
Any of these programs can be called in any order.

Set up the required components. [This subroutine COMP includes the property databank]. Then give molecular group count, y(i)

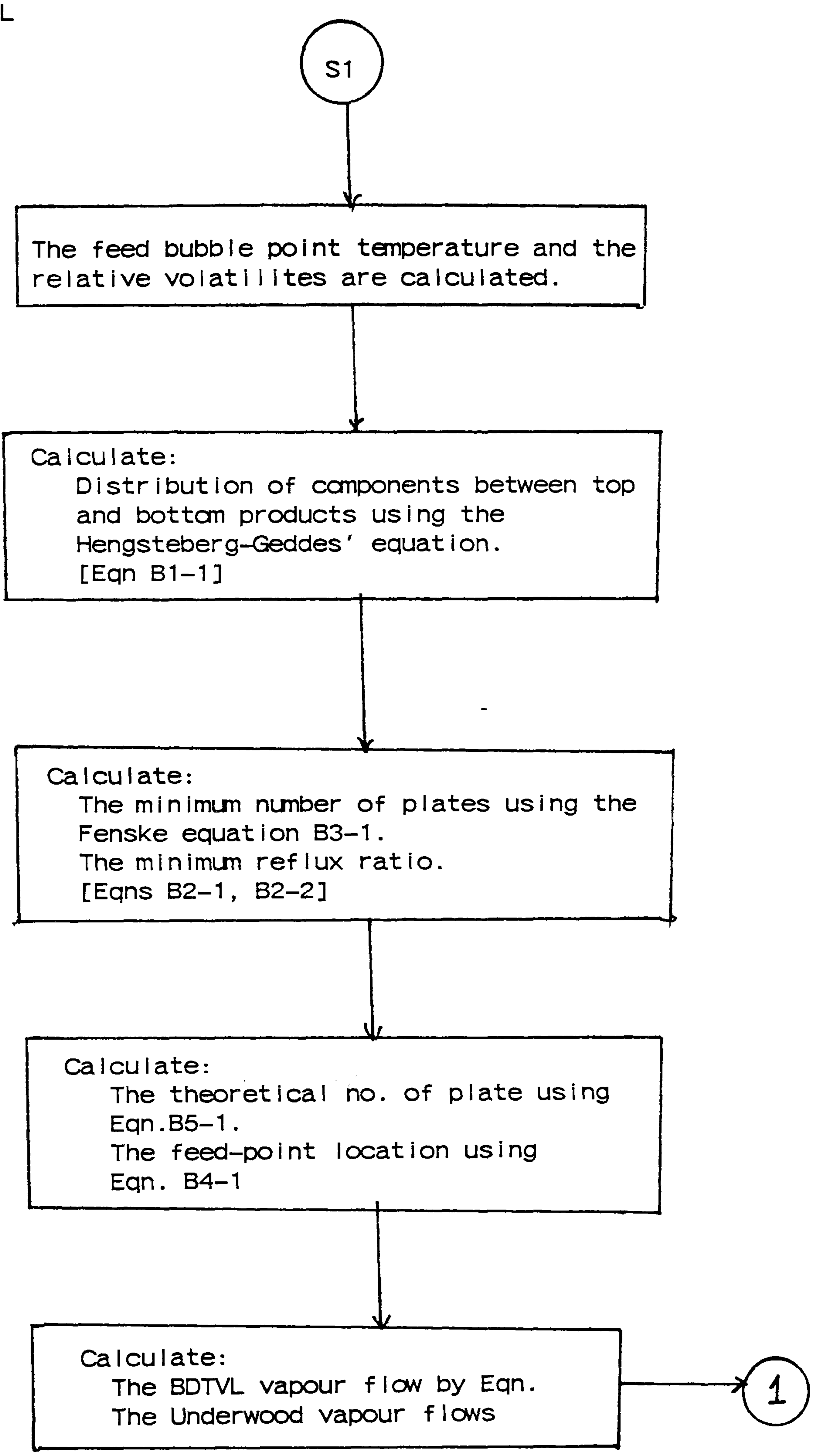
Give:

NOC - No. of components
NOCL - No. of columns
NOCONF-No. of sequences
BUBT - Condenser temp.
COLPDROP-Column pressure drop
CONPDROP-Condenser pessure drop
ALFA-relative volatility (when necessary)
DLK,BHK-recovery fractions
q-feed vaporisation
RRM-R/R_m
E - overall fractional column efficiency.


1
Extractive Distillation?
Y
N
Call EXTRACT
DO 20 KONFI=1,NOCONF
DO 21 KN = 1,NOCL
Process topology of the columns
Call DISCOL (S1) to determine
Product distribution.
Min. number of plates.
Min. reflux ratio.
Actual no. of plates.
Feed point location.
Vapour and liquid flow rates.
Pressures and temperatures at condenser, top, feed and bottom plates.
Vapour and liquid enthalpies.
Relative volatilites.
SHORTCUT ONLY?
Y
N
2
5
4
3


2
5
4
3
6
[Enter into the rigorous design.]
Call RDISCOL (S2) to determine the various material, enthalpy and equilibrium balances; the reboiler and condenser heat loads, etc.
[Cost analyses stage]
Call COST (S3) to determine capital costs of column, condenser and reboiler. the cooling water cost and the steam cost.
N
IS KN = NOCL?
Y
N
IS KONFI = NOCONF?
Y
PRINT RESULTS.

F- 2 DISCOL



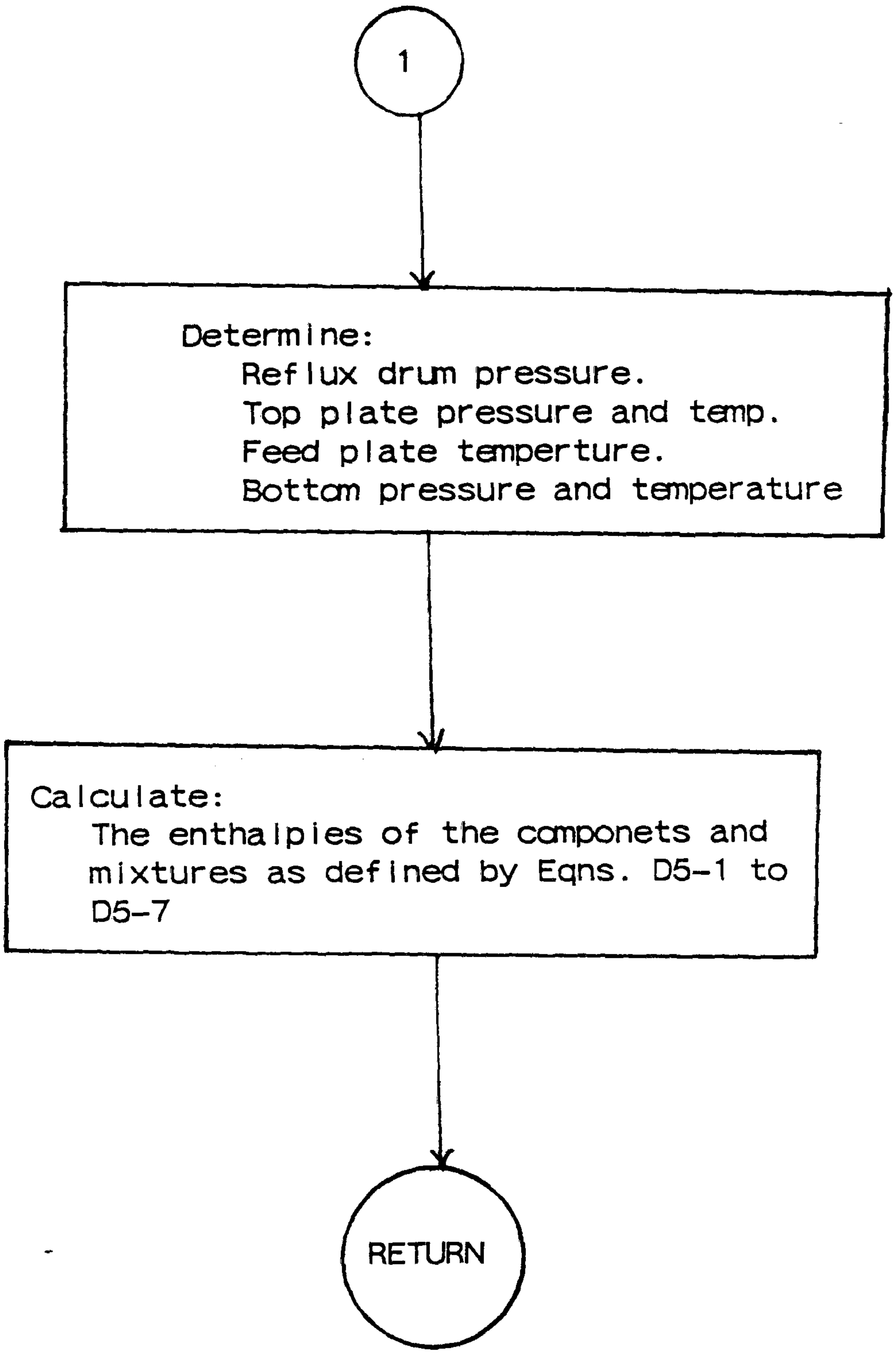
The feed bubble point temperature and the relative volatilites are calculated.

Calculate:
Distribution of components between top and bottom products using the Hengsteberg-Geddes' equation.
[Eqn B1-1]

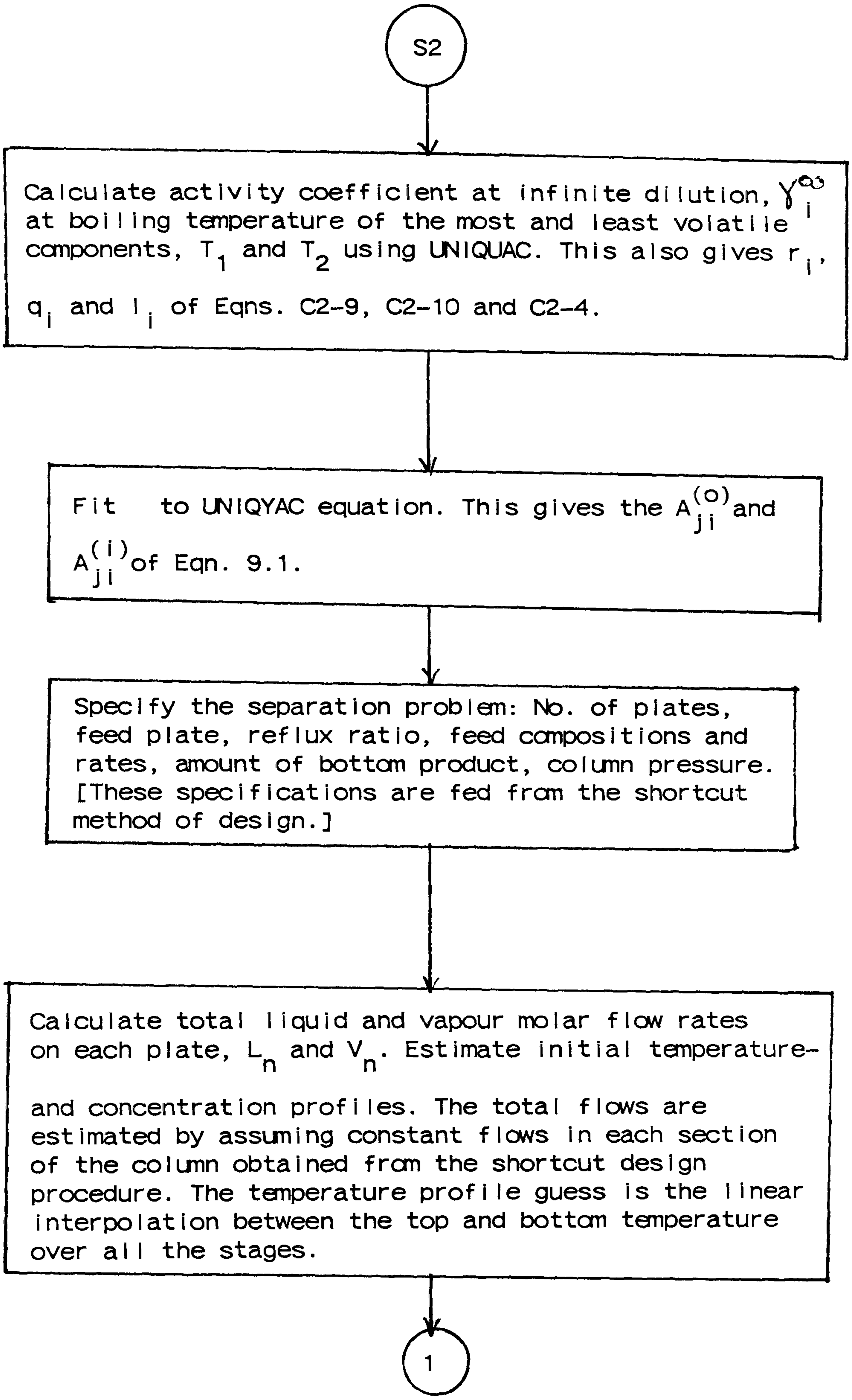
Calculate:
The minimum number of plates using the Fenske equation B3-1.
The minimum reflux ratio.
[Eqns B2-1, B2-2]

Calculate:
The theoretical no. of plate using Eqn.B5-1.
The feed-point location using Eqn. B4-1

Calculate:
The BDTVL vapour flow by Eqn.
The Underwood vapour flows


1
Determine:
Reflux drum pressure.
Top plate pressure and temp.
Feed plate temperture.
Bottom pressure and temperature
Calculate:
The enthalpies of the componets and mixtures as defined by Eqns. D5-1 to D5-7
RETURN

F-3 RDISCOL [Fredenslund et al(1977)]

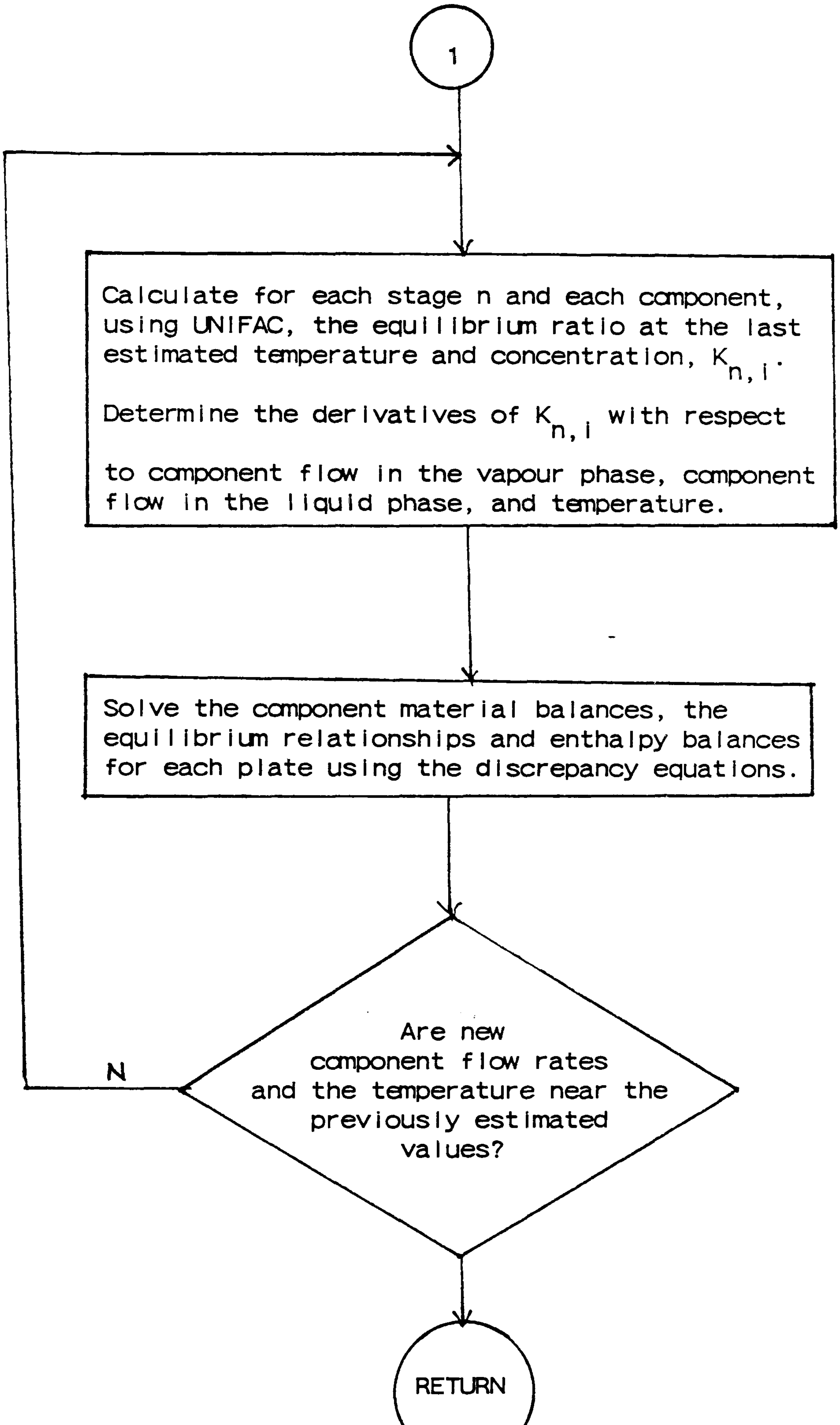


Calculate activity coefficient at infinite dilution, γ_i^{∞} at boiling temperature of the most and least volatile components, T_1 and T_2 using UNIQUAC. This also gives r_i, q_i and l_i of Eqns. C2-9, C2-10 and C2-4.

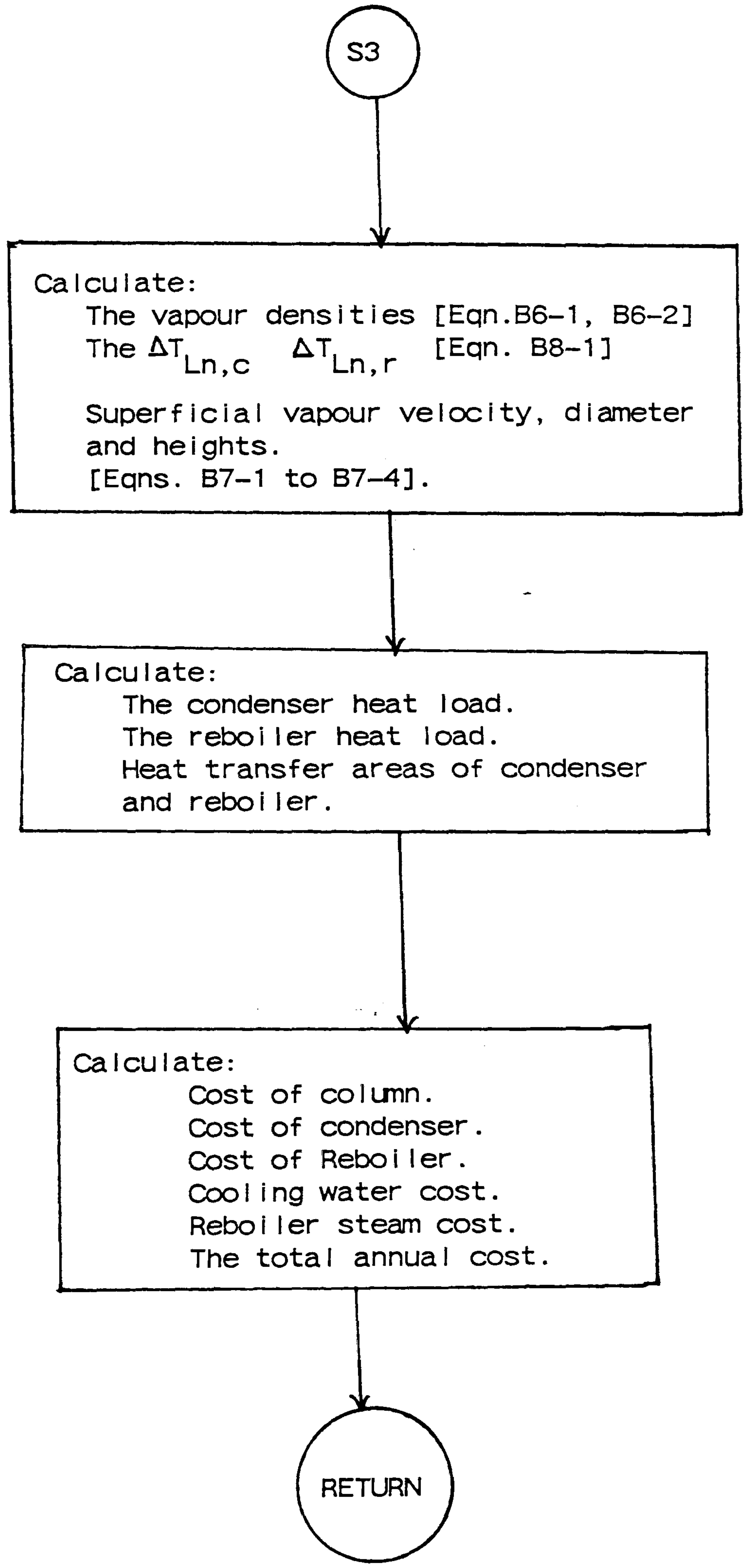
Fit to UNIQYAC equation. This gives the $A_{ji}^{(o)}$ and $A_{ji}^{(i)}$ of Eqn. 9.1.

Specify the separation problem: No. of plates, feed plate, reflux ratio, feed compositions and rates, amount of bottom product, column pressure. [These specifications are fed from the shortcut method of design.]

Calculate total liquid and vapour molar flow rates on each plate, L_n and V_n. Estimate initial temperature- and concentration profiles. The total flows are estimated by assuming constant flows in each section of the column obtained from the shortcut design procedure. The temperature profile guess is the linear interpolation between the top and bottom temperature over all the stages.


1
Calculate for each stage n and each component, using UNIFAC, the equilibrium ratio at the last estimated temperature and concentration, $K_{n,i}$.
Determine the derivatives of $K_{n,i}$ with respect to component flow in the vapour phase, component flow in the liquid phase, and temperature.
Solve the component material balances, the equilibrium relationships and enthalpy balances for each plate using the discrepancy equations.
Are new component flow rates and the temperature near the previously estimated values?
N
RETURN

F-4 COST


S3
Calculate:
The vapour densities [Eqn.B6-1, B6-2]
The $\Delta T_{Ln,c}$ $\Delta T_{Ln,r}$ [Eqn. B8-1]
Superficial vapour velocity, diameter and heights.
[Eqns. B7-1 to B7-4].
Calculate:
The condenser heat load.
The reboiler heat load.
Heat transfer areas of condenser and reboiler.
Calculate:
Cost of column.
Cost of condenser.
Cost of Reboiler.
Cooling water cost.
Reboiler steam cost.
The total annual cost.
RETURN

APPENDIX G

SOME SAMPLE COMPUTER OUTPUT RESULTS

TABLE G1-1: Sample computer output result for the optimum values of R/R_m, N/N_m, total annual cost per energy cost and the total annual cost per distillate for operating pressure of 0.066 atm. [Ref. to Tables A3.2 and A3.7]

```
****************************************************************************************************************************
***************
***************   Pdn =   7            2299-DJT          Terminal:  82                4 NOV 86 21:03:14          Vos 4.1 ***************
***************                                                                                                           ***************
****************************************************************************************************************************
****************************************************************************************************************************

LISTING OF 2299DJT *COUT      LAST UPDATED ON  4-NOV-86 AT 21:02:55

 ===> AS 20=*
 ===> AS 7=*
 ===> XE

          ** ENTERING CONTROL SECTION **


    THE COMPONENTS ARE:

    (28)ETHYLBENZENE
    (29)STYRENE

          ** ENTERING CONTROL SECTION **

 XD(1)=    0.99000     XB(1)=     1.00000E-02

    OPERATING PRESSURE, ATM =       0.066

                XF(1)=0.10                              XF(1)=0.25                                 XF(1)=0.50

 ALFA  OPTRF  OPTNF   VO   TOTDE  TOTLD        OPTRF  OPTNF    VO   TOTDE  TOTLD          OPTRF  OPTNF    VO   TOTDE  TOTLD
 1.05 1.0793 1.339   85.3 4.568 3703939.5    1.0810 1.341    85.3 4.575 1492491.6     1.0823 1.343    85.3 4.579  751212.1
 1.10 1.0866 1.473   85.4 3.023 1239646.0    1.0884 1.476    85.4 3.027  502958.4     1.0907 1.477    85.4 3.027  255938.1
 1.20 1.0877 1.673   85.7 2.212  458663.8    1.0905 1.675    85.7 2.213  188546.5     1.0945 1.671    85.7 2.211   97941.3
 1.50 1.0818 2.082   86.3 1.691  143703.4    1.0870 2.072    86.3 1.688   61301.5     1.0951 2.047    86.3 1.681   33633.0
 2.25 1.0733 2.689   87.2 1.468   53009.9    1.0832 2.633    87.2 1.460   24504.4     1.0989 2.546    87.2 1.448   14898.3
 3.00 1.0711 3.057   87.2 1.376   33427.4    1.0850 2.950    87.2 1.386   16503.6     1.1071 2.805    87.2 1.371   10775.4



                          XF(1)=0.75                                XF(1)=0.90

                   ALFA  OPTRF  OPTNF    VO   TOTDE  TOTLD        OPTRF  OPTNF    VO   TOTDE  TOTLD
                   1.05 1.0835 1.343   85.3 4.580  496714.7     1.0844 1.343   85.3 4.580  390845.0
                   1.10 1.0928 1.476   85.4 3.026  171007.3     1.0945 1.474   85.4 3.024  135349.7
                   1.20 1.0984 1.665   85.7 2.206   66703.7     1.1017 1.659   85.7 2.203   53349.6
                   1.50 1.1034 2.021   86.3 1.673   24012.4     1.1109 1.999   86.3 1.667   19678.7
                   2.25 1.1156 2.467   87.2 1.437   11482.3     1.1332 2.397   87.2 1.427    9749.0
                   3.00 1.1312 2.684   87.2 1.359    8691.2     1.1612 2.567   87.2 1.347    7516.9
 ***************************************************************


                    XF(1)=0.10                         XF(1)=0.25                           XF(1)=0.50

     ALFA       QDAREA       Y22M      Y11M       QDAREA      Y22M      Y11M       QDAREA       Y22M      Y11M
     1.05     309396.67      71.48     4.23     309396.67     71.48     4.23     309396.67     71.48     4.23
     1.10     310056.64      71.63     4.32     310056.64     71.63     4.32     310056.64     71.63     4.32
     1.20     311285.07      71.91     4.50     311285.07     71.91     4.50     311285.07     71.91     4.50
     1.50     314400.43      72.63     5.10     314400.43     72.63     5.10     314400.43     72.63     5.10
     2.25     318973.28      73.67     6.68     318973.28     73.67     6.68     318973.28     73.67     6.68





     3.00     319011.16      73.66     6.68     319011.16     73.66     6.68     319011.16     73.66     6.68
```

TABLE G1-2: Sample computer output result displaying complete output for the sizing and costing of sequences of a three-component mixture No. 1 of n-Butane, i-Pentane and n-Pentane [Ref. to Table A4.8]

```
******************************************************************************************************
******************************************************************************************************
**************
**************   Pdn =   6             2299-DJT            Prog: Sys Boot              17 NOV 86 15:30:01
**************
******************************************************************************************************
******************************************************************************************************


LISTING OF 2299DJT *COUT1    LAST UPDATED ON 17-NOV-86 AT 13:53:00

      ===> AS 20=DATA3
      ===> XE

                ** ENTERING CONTROL SECTION **


           THE COMPONENTS ARE:

           (4)N-BUTANE
           (5)I-PENTANE
           (6)N-PENTANE

                ** ENTERING CONTROL SECTION **


      ** FILE USE31     OPENED TO CHANNEL    8

           FD   =     100.00

           PRESSURE OF FEED (ATM.)   =     4.123 ATM.


           SEQUENCE NUMBER  =    1
           COLUMN NUMBER    =    1

           THE FEED COMPOSITION AND THE RELATIVE VOLATILITIES ARE

          I     XF(I)   ALFA(I)     KV(I)  ALFA1(I)
          1    0.8000    2.4140    1.1447    2.4140
          2    0.1000    1.0000    0.4742    1.2872
          3    0.1000    0.7769    0.3684    0.0000

           THE SPECIFIED MOLE FRACTIONS OF THE KEYS IN THE DISTILLATE
           AND IN THE BOTTOMS ARE

                XD(HK) =     0.0050      XB(LK) =     0.0050

           THE RECOVERY FRACTION AT TOP OF COLUMN

                DFLK    =    0.9900      BFHK    =    0.9900

           MINIMUN NO. OF PLATES =  10.43
           AT REFLUX RATIO, R  =  0.876       NO. OF ACTUAL PLATES = 26.565
           PHI =  1.083466     MINIMUN REFLUX RATIO, RMIN =  0.814

           USE TOTAL REFLUX CONDENSER

           REFLUX DRUM PRESSURE (ATM.)=        4.04
           COLUMN TOP PRESSURE (ATM.) =        4.38
```

Table G1-2 (Continued)

```
    BOTTOM PRESSURE (ATM.)      =      4.72

    TEMP. OF REFLUX DRUM, K       =      322.0
    BUBBLE-PT. TEMP. IN BOTTOM, K  =      365.2
    FEED TEMP(C)=      77.67     FEED-POINT =    10
SUBROUTINE DISCOL IS FULLY EXECUTED

 N-BUTANE, I-PENTANE, N-PENTANE

    THE CHOSEN R/RM =     1.1000

    HEAT TO BE SUPPLIED IN THE REBOILER (KJ/HR)=           2569736.45
    HEAT TO BE REMOVED BY THE CONDENSER (KJ/HR)=           1389709.88

    DIAMETER OF COLUMN (M) =     0.6508
    HEAT TRANSFER AREA OF CONDENSER (M2) =    36.0559
    HEAT TRANSFER AREA OF REBOLIER (M2)  =    28.5526

    dT BTW. REBOILER AND CONDENSER =      43.24
    QcdT  =            60091436.66
    QrdT  =           111116109.33
    ENTROPY CHANGE =                355905.02
****************************************************
****************************************************
    FD  =    20.000

    PRESSURE OF FEED (ATM.)  =      1.737 ATM.


    SEQUENCE NUMBER  =    1
    COLUMN NUMBER    =    2

    THE FEED COMPOSITION AND THE RELATIVE VOLATILITIES ARE

   I     XF(I)   ALFA(I)     KV(I)  ALFA1(I)
   1    0.0000    1.1436    1.0000    0.8884
   2    0.5000    1.2872    1.1256    1.2872
   3    0.5000    1.0000    0.8744    0.0000

    THE SPECIFIED MOLE FRACTIONS OF THE KEYS IN THE DISTILLATE
    AND IN THE BOTTOMS ARE

         XD(HK) =     0.0050     XB(LK) =     0.0050

    THE RECOVERY FRACTION AT TOP OF COLUMN

         DFLK    =    0.9900      BFHK    =    0.9900

    MINIMUN NO. OF PLATES =  36.40
    AT REFLUX RATIO, R   =  7.485       NO. OF ACTUAL PLATES = 64.627
    PHI =  1.125571      MINIMUN REFLUX RATIO, RMIN =  6.964

    USE TOTAL REFLUX CONDENSER

    REFLUX DRUM PRESSURE (ATM.)=      1.36
    COLUMN TOP PRESSURE (ATM.) =      1.70
    BOTTOM PRESSURE (ATM.)     =      2.04

    TEMP. OF REFLUX DRUM, K       =      322.0
    BUBBLE-PT. TEMP. IN BOTTOM, K  =      342.1
```

TABLE G1-2: (Continued)

```
    FEED TEMP(C)=      59.03     FEED-POINT =    33
SUBROUTINE DISCOL IS FULLY EXECUTED

 N-BUTANE, I-PENTANE, N-PENTANE

    THE CHOSEN R/RM =      1.1000

    HEAT TO BE SUPPLIED IN THE REBOILER (KJ/HR)=           2011309.01
    HEAT TO BE REMOVED BY THE CONDENSER (KJ/HR)=           1798357.83

    DIAMETER OF COLUMN (M) =     0.6540
    HEAT TRANSFER AREA OF CONDENSER (M2) =     46.6583
    HEAT TRANSFER AREA OF REBOLIER (M2)  =     22.3479

    dT BTW. REBOILER AND CONDENSER =      20.07
    QcdT  =            36097160.92
    QrdT  =            40371578.80
    ENTROPY CHANGE =              123622.10

    SUM OF ENTROPY CHANGE FOR THE SEQUENCE =            479527.12
    SUM OF QcdT FOR THE SEQUENCE =          96188597.58
****************************************************
****************************************************
    FD   =     100.00

    PRESSURE OF FEED (ATM.)   =      4.123 ATM.


    SEQUENCE NUMBER   =     2
    COLUMN NUMBER     =     1

    THE FEED COMPOSITION AND THE RELATIVE VOLATILITIES ARE

   I      XF(I)    ALFA(I)      KV(I)  ALFA1(I)
   1     0.8000     3.1073     1.1447     2.4140
   2     0.1000     1.2872     0.4742     1.2872
   3     0.1000     1.0000     0.3684     0.0000

    THE SPECIFIED MOLE FRACTIONS OF THE KEYS IN THE DISTILLATE
    AND IN THE BOTTOMS ARE

         XD(HK) =     0.0050      XB(LK) =     0.0050

    THE RECOVERY FRACTION AT TOP OF COLUMN

         DFLK     =     0.9900      BFHK     =     0.9900

    MINIMUN NO. OF PLATES =  36.40
    AT REFLUX RATIO, R   =  1.035      NO. OF ACTUAL PLATES = 65.486
    PHI =  1.056495      MINIMUN REFLUX RATIO, RMIN =  0.967

    USE TOTAL REFLUX CONDENSER

    REFLUX DRUM PRESSURE (ATM.)=       3.73
    COLUMN TOP PRESSURE (ATM.) =       4.07
    BOTTOM PRESSURE (ATM.)     =       4.41

    TEMP. OF REFLUX DRUM, K        =      322.0
    BUBBLE-PT. TEMP. IN BOTTOM, K  =      367.1
    FEED TEMP(C)=      76.57     FEED-POINT =    26
```

TABLE G1-2 : (Continued)

```
SUBROUTINE DISCOL IS FULLY EXECUTED

 N-BUTANE, I-PENTANE, N-PENTANE

    THE CHOSEN R/RM =     1.1000

    HEAT TO BE SUPPLIED IN THE REBOILER (KJ/HR)=          3385616.61
    HEAT TO BE REMOVED BY THE CONDENSER (KJ/HR)=          1973766.04

    DIAMETER OF COLUMN (M) =     0.7378
    HEAT TRANSFER AREA OF CONDENSER (M2) =     51.2093
    HEAT TRANSFER AREA OF REBOLIER (M2)  =     37.6180

    dT BTW. REBOILER AND CONDENSER =      45.06
    QcdT  =          88946670.78
    QrdT  =         152570932.59
    ENTROPY CHANGE =           474433.55
****************************************************
****************************************************
    FD  =     90.000

    PRESSURE OF FEED (ATM.)  =      4.412 ATM.


    SEQUENCE NUMBER  =     2
    COLUMN NUMBER    =     2

    THE FEED COMPOSITION AND THE RELATIVE VOLATILITIES ARE

   I     XF(I)   ALFA(I)     KV(I)  ALFA1(I)
   1     0.8889   2.4140    1.0696    2.4140
   2     0.1111   1.0000    0.4431    0.4396
   3     0.0000   2.2746    1.0078    0.0000

    THE SPECIFIED MOLE FRACTIONS OF THE KEYS IN THE DISTILLATE
    AND IN THE BOTTOMS ARE

         XD(HK) =     0.0050      XB(LK) =     0.0050

    THE RECOVERY FRACTION AT TOP OF COLUMN

         DFLK    =    0.9900      BFHK    =    0.9900

    MINIMUN NO. OF PLATES =  10.43
    AT REFLUX RATIO, R  =  0.853      NO. OF ACTUAL PLATES = 26.571
    PHI =  1.069612      MINIMUN REFLUX RATIO, RMIN =  0.796

    USE TOTAL REFLUX CONDENSER

    REFLUX DRUM PRESSURE (ATM.)=       4.04
    COLUMN TOP PRESSURE (ATM.) =       4.38
    BOTTOM PRESSURE (ATM.)     =       4.72

    TEMP. OF REFLUX DRUM, K        =      322.0
    BUBBLE-PT. TEMP. IN BOTTOM, K  =      361.2
    FEED TEMP(C)=      76.40     FEED-POINT =     9
SUBROUTINE DISCOL IS FULLY EXECUTED

 N-BUTANE, I-PENTANE, N-PENTANE

```

TABLE G1-2: (Continued)

```
      THE CHOSEN R/RM =     1.1000

      HEAT TO BE SUPPLIED IN THE REBOILER (KJ/HR)=          2526106.12
      HEAT TO BE REMOVED BY THE CONDENSER (KJ/HR)=          1348028.31

      DIAMETER OF COLUMN (M) =     0.6441
      HEAT TRANSFER AREA OF CONDENSER (M2) =    34.9745
      HEAT TRANSFER AREA OF REBOLIER (M2)  =    28.0678

      dT BTW. REBOILER AND CONDENSER =     39.16
      QcdT  =          52790395.61
      QrdT  =          98925327.37
      ENTROPY CHANGE =            327260.64

      SUM OF ENTROPY CHANGE FOR THE SEQUENCE =          801694.19
      SUM OF QcdT FOR THE SEQUENCE =         141737066.39
  ***************************************************
  ***************************************************

      THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

     I      XFO(I)   ALFA(I)   ALFA1(I)    COMPONENT
     1    0.8000   2.4140    2.4140     (4)N-BUTANE
     2    0.1000   1.0000    0.4396     (5)I-PENTANE
     3    0.1000   2.2746    0.0000     (6)N-PENTANE

      FEED RATE =  100.0000KMOLE/HR


      CONF. NO.      COL. NO.      CAPITAL COSTS     ENERGY COSTS     TOTAL ANNUAL COSTS

          1             1               32234.8         205452.1           237686.9

          1             2               40106.1         159052.5           199158.6

      TOTAL COST OF THE SEQUENCE       72340.9         364504.6           436845.5



          2             1               62195.7         272052.9           334248.7

          2             2               31610.5         200711.7           232322.2

      TOTAL COST OF THE SEQUENCE       93806.2         472764.7           566570.9



      TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

      KONFI             VAPOUR FLOW (BDTVL)  CORRECTED VAPOUR FLOW     VAP.(UNDERWOOD)

        1                  2.4440                       2.0112               2.3826

        2                  6.2302                       4.8892               3.3572
```

TABLE G1-3: Sample computer output result for a four-component feedstock No. 1 at different feed compositions. [Ref. to Table 4.6]

```
     THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

    I       XFO(I)    ALFA(I)    ALFA1(I)     COMPONENT
    1     0.2500     2.4101     0.6309      (3)I-BUTANE
    2     0.2500     3.8201     3.0201      (5)I-PENTANE
    3     0.2500     1.0000     0.4040      (8)N-HEXANE
    4     0.2500     2.4751     0.0000      (10)N-HEPTANE

     FEED RATE =   100.0000KMOLE/HR


     CONF. NO.        COL. NO.      CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

         1               1              10645.1          121424.3              132069.4

         1               2              13106.9          106107.1              119214.0

         1               3              18848.1          149120.3              167968.4

     TOTAL COST OF THE SEQUENCE         42600.0          376651.7              419251.8



         2               1              15687.9          139804.5              155492.4

         2               2               9100.8           71674.7               80775.5

         2               3              18848.1          149120.3              167968.4

     TOTAL COST OF THE SEQUENCE         43636.8          360599.6              404236.3



         3               1              26868.4          194700.5              221568.9

         3               2               9927.7           93303.7              103231.3

         3               3              11942.7           84082.9               96025.6

     TOTAL COST OF THE SEQUENCE         48738.8          372087.1              420825.9



         4               1              26868.4          194700.5              221568.9

         4               2              14653.8          109969.9              124623.7

         4               3               9100.8           71674.7               80775.5

     TOTAL COST OF THE SEQUENCE         50623.0          376345.1              426968.1



         5               1              10645.1          121424.3              132069.4

         5               2              24322.4          173105.6              197428.0

         5               3              11942.7           84082.9               96025.6

     TOTAL COST OF THE SEQUENCE         46910.2          378612.9              425523.1
```

TABLE G1-3: (Continued)

```
******************************************************************

     THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

   I        XFO(I)     ALFA(I)    ALFA1(I)     COMPONENT
   1     0.7000     2.4101     0.6309       (3)I-BUTANE
   2     0.1000     3.8201     3.8201       (5)I-PENTANE
   3     0.1000     1.0000     0.4040       (8)N-HEXANE
   4     0.1000     2.4751     0.0000       (10)N-HEPTANE

     FEED RATE =   100.0000KMOLE/HR


     CONF. NO.        COL. NO.        CAPITAL COSTS       ENERGY COSTS       TOTAL ANNUAL COSTS





          1               1              18779.5            106722.3              125501.8

          1               2               5242.8             42443.0               47685.7

          1               3               7539.3             59648.5               67187.8

     TOTAL COST OF THE SEQUENCE          31561.5            208813.8              240375.3



          2               1              16017.9             85514.3              101532.2

          2               2              18614.1            117731.4              136345.6

          2               3               7539.3             59648.5               67187.8

     TOTAL COST OF THE SEQUENCE          42171.3            262894.2              305065.5



          3               1              19721.8            107710.7              127432.5

          3               2              18524.6            107128.1              125652.7

          3               3               4777.1             33633.5               38410.6

     TOTAL COST OF THE SEQUENCE          43023.5            248472.3              291495.8



          4               1              19721.8            107710.7              127432.5

          4               2              15602.3             75871.0               91473.3

          4               3              18614.1            117731.4              136345.6

     TOTAL COST OF THE SEQUENCE          53938.2            301313.1              355251.3



          5               1              18779.5            106722.3              125501.8

          5               2               9729.0             69242.4               78971.4

          5               3               4777.1             33633.5               38410.6

     TOTAL COST OF THE SEQUENCE          33285.6            209598.2              242883.8
```

TABLE G1-3 (Continued)

```
**************************************************************

     THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

    I        XFO(I)    ALFA(I)   ALFA1(I)     COMPONENT
    1      0.1000     3.4676    0.9077       (3)I-BUTANE
    2      0.7000     3.8201    3.8201       (5)I-PENTANE
    3      0.1000     1.0000    0.2878       (8)N-HEXANE
    4      0.1000     3.4749    0.0000       (10)N-HEPTANE

     FEED RATE =  100.0000KMOLE/HR


     CONF. NO.      COL. NO.      CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

         1              1              11090.5          133114.9              144205.3

         1              2              25773.4          146581.4              172354.9

         1              3               7539.3           59648.5               67187.8

     TOTAL COST OF THE SEQUENCE        44403.2          339344.8              383748.0



         2              1              26710.7          155434.0              182144.7

         2              2              10225.4          109238.8              119464.2

         2              3               7539.3           59648.5               67187.8

     TOTAL COST OF THE SEQUENCE        44475.4          324321.3              368796.7



         3              1              27010.2          140675.4              168485.6

         3              2              10668.1          120208.1              130876.2

         3              3              25522.2          146503.8              172026.0

     TOTAL COST OF THE SEQUENCE        64000.4          407387.3              471387.7



         4              1              27010.2          140675.4              168485.6

         4              2              26494.1          155309.3              181883.4

         4              3              10225.4          109238.8              119464.2

     TOTAL COST OF THE SEQUENCE        64529.7          405303.5              469833.2



         5              1              11090.5          133114.9              144205.3

         5              2              26455.7          136042.5              162498.2

         5              3              25522.2          146503.8              172026.0

     TOTAL COST OF THE SEQUENCE        63068.4          415661.1              478729.5
```

TABLE G1-3: (Continued)

```
 THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

 I       XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
 1     0.1000    1.3525    0.3540     (3)I-BUTANE
 2     0.1000    3.8201    3.8201     (5)I-PENTANE
 3     0.7000    1.0000    0.7238     (8)N-HEXANE
 4     0.1000    1.3815    0.0000     (10)N-HEPTANE

 FEED RATE =   100.0000KMOLE/HR


 CONF. NO.       COL. NO.       CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

     1              1                 6595.5          120158.5              126754.0

     1              2                12980.7          130115.4              143096.1

     1              3                38137.9          247352.7              285490.6

 TOTAL COST OF THE SEQUENCE          57714.0          497626.7              555340.7



     2              1                12432.6          161660.1              174092.7

     2              2                 3640.3           28670.3               32310.6

     2              3                38137.9          247352.7              285490.6

 TOTAL COST OF THE SEQUENCE          54210.8          437603.2              491894.0



     3              1                42376.4          262877.8              305254.2

     3              2                 6241.3          105445.8              111687.1

     3              3                12438.6          119285.4              131724.1


 TOTAL COST OF THE SEQUENCE          61056.4          487609.1              548665.4



     4              1                42376.4          262877.8              305254.2

     4              2                11706.4          146798.4              158704.8

     4              3                 3640.3           28670.3               32310.6

 TOTAL COST OF THE SEQUENCE          57923.2          438346.5              496269.7



     5              1                 6595.5          120158.5              126754.0

     5              2                40711.3          259662.1              300373.4

     5              3                12438.6          119285.4              131724.1

 TOTAL COST OF THE SEQUENCE          59745.4          499106.0              558851.4
```

TABLE G1-3: (Continued)

```
 THE FEED CONPOSTIONS AND RELATIVE VOLATILITIES ARE

 I        XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
 1      0.1000     2.4101    0.6309      (3)I-BUTANE
 2      0.1000     3.8201    3.8201      (5)I-PENTANE
 3      0.1000     1.0000    0.4040      (8)N-HEXANE
 4      0.7000     2.4751    0.0000      (10)N-HEPTANE

 FEED RATE =  100.0000KMOLE/HR


 CONF. NO.       COL. NO.      CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

     1              1               6260.6          146628.9              152889.5

     1              2               8198.8          108109.5              116308.3

     1              3              21640.0          219292.7              240932.7

 TOTAL COST OF THE SEQUENCE         36099.4          474031.1              510130.5



     2              1               9220.4          156966.8              166187.2

     2              2               3640.3           28670.3               32310.6

     2              3              21640.0          219292.7              240932.7

 TOTAL COST OF THE SEQUENCE         34500.8          404929.8              439430.6



     3              1              20439.9          238924.5              259364.4

     3              2               3771.1           37521.7               41292.8

     3              3               4777.1           33633.5               38410.6

 TOTAL COST OF THE SEQUENCE         29188.1          309879.8              339067.9



     4              1              20439.9          238924.5              259364.4

     4              2               5861.5           43988.2               49849.8

     4              3               3640.3           28670.3               32310.6

 TOTAL COST OF THE SEQUENCE         29741.8          311583.1              341524.7




     5              1               6260.6          146628.9              152889.5

     5              2              21471.7          217669.6              239141.3

     5              3               4777.1           33633.5               38410.6

 TOTAL COST OF THE SEQUENCE         32509.5          397931.9              430441.4
```

TABLE G1-4: Sample computer output result for a four-component feedstock No. 4 [Ref. to Table A4.6]

```
     THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

     I       XFO(I)    ALFA(I)   ALFA1(I)     COMPONENT
     1     0.2500     1.9034    0.6781       (13)TRANS-2-BUTENE
     2     0.2500     2.8068    2.8068       (14)CIS-2-BUTENE
     3     0.2500     1.0000    0.5163       (6)N-PENTANE
     4     0.2500     1.9369    0.0000       (8)N-HEXANE
           .
     FEED RATE =   100.0000KMOLE/HR


     CONF. NO.         COL. NO.       CAPITAL COSTS       ENERGY COSTS        TOTAL ANNUAL COSTS

         1                1                 487488.0           1208606.9               1696095.0

         1                2                  13493.9            111759.2                125253.1

         1                3                  15593.9            108268.5                123862.4

     TOTAL COST OF THE SEQUENCE             516577.8           1428634.7               1945212.5



         2                1                  21029.9            158726.9                179756.8

         2                2                 447248.2           1142175.9               1589424.1

         2              _ 3                  15593.9            108268.5                123862.4

     TOTAL COST OF THE SEQUENCE             483872.0           1409171.4               1893043.4



         3                1                  24453.3            167531.9                191985.2

         3                2                 468336.6           1176630.2               1644966.8

         3                3                  12370.2             92414.4                104784.6

     TOTAL COST OF THE SEQUENCE             505160.1           1436576.4               1941736.6

        -

         4                1                  24453.3            167531.9                191985.2

         4                2                  20066.8            142597.3                162664.1

         4                3                 447248.2           1142175.7               1589424.1

     TOTAL COST OF THE SEQUENCE             491768.4           1452305.1               1944073.5



         5                1                 487488.0           1208606.9               1696095.0

         5                2                  17772.7            140512.8                160285.5

         5                3                  12370.2             92414.4                104784.6

     TOTAL COST OF THE SEQUENCE             519630.9           1441534.1               1961165.0
```

TABLE G1-5: Sample computer output result for a three-component mixture of Benzene, Toluene and o-Xylene. [Ref. to Table 5.5]

```
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     THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

    I       XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
    1     0.3700     2.8664    2.8664      (23)BENZENE
    2     0.3700     1.0000    2.6200      (24)TOLUENE
    3     0.2600     0.3817    0.0000      (25)O-XYLENE

     FEED RATE =  270.0000KMOLE/HR


     CONF. NO.      COL. NO.      CAPITAL COSTS     ENERGY COSTS     TOTAL ANNUAL COSTS

         1             1               79242.5         740561.0              819803.5

         1             2               83671.4         754095.9              838567.3

     TOTAL COST OF THE SEQUENCE       162913.9        1495456.9             1658370.8



         2             1              116149.9         988724.0             1104873.9

         2             2               74396.0         636208.9              710604.9

     TOTAL COST OF THE SEQUENCE       190545.9        1624932.9             1815478.8



     TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

     KONFI            VAPOUR FLOW          CORRECTED VAPOUR FLOW     VAP.(UNDERWOOD)

       1                 1.7571                          1.5105             1.6308

       2                 2.2251                          1.9118             1.9849

          ** ENTERING CONTROL SECTION **


     THE COMPONENTS ARE:
```

TABLE G1-5 (Continued)

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     THE FEED CONPOSTIONS AND REIATIVE VOLATILITIES ARE

   I       XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
   1     0.3300    2.8664    2.8664      (23)BENZENE
   2     0.3300    1.0000    2.6200      (24)TOLUENE
   3     0.3400    0.3817    0.0000      (25)O-XYLENE

     FEED RATE =   300.0000KMOLE/HR


     CONF. NO.        COL. NO.      CAPITAL COSTS     ENERGY COSTS      TOTAL ANNUAL COSTS

          1              1               81174.8         804346.1               885520.8

          1              2               92828.5         875472.6               968301.1

     TOTAL COST OF THE SEQUENCE         174003.2        1679818.6              1853821.9



         2-              1              122806.8        1095983.3              1218790.1

         2               2               73725.7         630477.3               704203.0

     TOTAL COST OF THE SEQUENCE         196532.5        1726460.6              1922993.1



     TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

     KONFI             VAPOUR FLOW          CORRECTED VAPOUR FLOW     VAP. (UNDERWOOD)

       1                   1.7043                          1.4651               1.5398

       2                   2.0580                          1.7682               1.8245

```

TABLE G1-6: Sample computer output result for a three-component feedstock No.2 [Ref. to Table A5.6]

```
 THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

 I      XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
 1     0.3300    1.3714    1.3714      (3)I-BUTANE
 2     0.3300    1.0000    1.3929      (4)N-BUTANE
 3     0.3400    0.7179    0.0000      (7)NEO-PENTANE

 FEED RATE =  100.0000KMOLE/HR


 CONF. NO.       COL. NO.        CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

     1               1                70159.0          364192.7                434351.7

     1               2                66369.8          335518.1                401887.8

 TOTAL COST OF THE SEQUENCE          136528.7          699710.8                836239.5



     2               1                78091.5          400733.3                478824.8

     2               2                60459.3          316037.2                376496.5

 TOTAL COST OF THE SEQUENCE          138550.8          716770.6                855321.3



 TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

 KONFI               VAPOUR FLOW             CORRECTED VAPOUR FLOW      VAP.(UNDERWOOD)

   1                      5.4976                              4.3221              4.7721

   2                      5.7445                              4.5228              5.0490

```

TABLE G1-7: Sample computer output result for a three-component feedstock No. 5 [Ref. to Table A5.9]

```
 THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

I        XFO(I)     ALFA(I)   ALFA1(I)     COMPONENT
1      0.3300     1.0776      1.0776       (13)TRANS-2-BUTENE
2      0.3300     1.0000      8.3300       (14)CIS-2-BUTENE
3      0.3400     0.1200      0.0000       (8)N-HEXANE

 FEED RATE =   100.0000KMOLE/HR


 CONF. NO.        COL. NO.       CAPITAL COSTS      ENERGY COSTS      TOTAL ANNUAL COSTS

     1               1               629847.4          1565053.1             2194900.5

     1               2                 8565.3            83003.9               91569.2

 TOTAL COST OF THE SEQUENCE          638412.6          1648057.0             2286469.7



     2               1                14871.3           119227.8              134099.1

     2               2               590543.3          1507940.8             2098484.2

 TOTAL COST OF THE SEQUENCE          605414.6          1627168.7             2232583.3



 TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

 KONFI              VAPOUR FLOW             CORRECTED VAPOUR FLOW      VAP. (UNDERWOOD)

   1                    14.9358                            8.5674              10.1398

   2                    10.4957                            6.2241              10.4897

       ** ENTERING CONTROL SECTION **


 THE COMPONENTS ARE:
```

TABLE G1-8: Sample computer output result for a four-component feedstock No. 2 [Ref. to Table A5.2]

```
THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

I      XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
1     0.7000    4.2614    1.3714      (3)I-BUTANE
2     0.1000    3.1073    3.1073      (4)N-BUTANE
3     0.1000    1.0000    2.9678      (6)N-PENTANE
4     0.1000    0.3369    0.0000      (8)N-HEXANE

FEED RATE =   100.0000KMOLE/HR


CONF. NO.      COL. NO.      CAPITAL COSTS     ENERGY COSTS     TOTAL ANNUAL COSTS

   1              1               78620.6          390972.5              469593.0

   1              2                4963.1           42496.8               47459.9

   1              3                5497.5           38237.4               43734.9

TOTAL COST OF THE SEQUENCE        89081.2          471706.6              560787.8



   2              1               20532.9          125372.6              145905.5

   2              2               63725.3          326775.5              390500.8

   2              3                5497.5           38237.4               43734.9

TOTAL COST OF THE SEQUENCE        89755.7          490385.5              580141.2



   3              1               20871.6          107791.7              128663.3

   3              2               71022.0          357653.2              428675.1

   3              3                3797.6           28769.6               32567.2

TOTAL COST OF THE SEQUENCE        95691.1          494214.5              589905.6



   4              1               20871.6          107791.7              128663.3

   4              2               19645.1          122228.3              141873.4

   4              3               63725.3          326775.5              390500.8

TOTAL COST OF THE SEQUENCE       104242.0          556795.6              661037.6



   5              1               78620.6          390972.5              469593.0

   5              2                8008.4           57475.8               65484.3

   5              3                3797.6           28769.6               32567.2

TOTAL COST OF THE SEQUENCE        90426.6          477217.9              567644.4




TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

KONFI             VAPOUR FLOW        CORRECTED VAPOUR FLOW      VAP.(UNDERWOOD)

  1                  4.1302                       3.2745             3.4998

  2                  4.6032                       3.7306             4.3309

  3                  5.0290                       4.0720             4.4074

  4                  5.7982                       4.7603             5.2464

  5                  4.2339                       3.3638             3.5883

     ** ENTERING CONTROL SECTION **

    ** NORMAL EXIT **
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TABLE G1-9: Sample computer output result for a four-component feedstock No. 4 [Ref. to Table A5.3]

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   THE FEED COMPOSTIONS AND RELATIVE VOLATILITIES ARE

   I      XFO(I)    ALFA(I)   ALFA1(I)    COMPONENT
   1     0. 2500    3. 0246   1. 0776     (13)TRANS-2-BUTENE
   2     0. 2500    2. 8068   2. 8068     (14)CIS-2-BUTENE
   3     0. 2500    1. 0000   2. 9678     (6)N-PENTANE
   4     0. 2500    0. 3369   0. 0000     (8)N-HEXANE

   FEED RATE =   100. 0000KMOLE/HR


   CONF. NO.       COL. NO.       CAPITAL COSTS     ENERGY COSTS     TOTAL ANNUAL COSTS

       1               1               488019. 3        1211532. 5            1699551. 8

       1               2                13437. 3         110777. 1             124214. 4

       1               3                15593. 7         108267. 9             123861. 6

   TOTAL COST OF THE SEQUENCE          517050. 3        1430577. 5            1947627. 8



       2               1                20948. 7         157218. 2             178166. 9

       2               2               447381. 4        1142379. 7            1589761. 1

       2               3                15593. 7         108267. 9             123861. 6

   TOTAL COST OF THE SEQUENCE          483923. 8        1407865. 8            1891789. 6



       3               1                24453. 3         167533. 1             191986. 4

       3               2               468633. 7        1177073. 2            1646507. 0

       3               3                12370. 4          92415. 5             104785. 9

   TOTAL COST OF THE SEQUENCE          505457. 5        1437821. 9            1943279. 3



       4               1                24453. 3         167533. 1             191986. 4

       4               2                20067. 2         142599. 3             162666. 5

       4               3               447381. 4        1142379. 7            1589761. 1

   TOTAL COST OF THE SEQUENCE          491902. 0        1452512. 1            1944414. 1



       5               1               488019. 3        1211532. 5            1699551. 8

       5               2                19772. 7         140513. 9             160286. 6


       5               3                12370. 4          92415. 5             104785. 9

   TOTAL COST OF THE SEQUENCE          520162. 4        1444461. 9            1964624. 2



   TOTAL VAPOUR FLOW RATE PER MOLE OF FEED

   KONFI           VAPOUR FLOW         CORRECTED VAPOUR FLOW      VAP. (UNDERWOOD)

     1              15. 6614                      9. 1718               8. 5318

     2               8. 9759                      5. 5342               8. 8147

     3              12. 7448                      7. 7208               9. 0037

     4               9. 6032                      6. 0750               9. 3117

     5              15. 8989                      9. 3768               8. 7562

        ** ENTERING CONTROL SECTION **

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