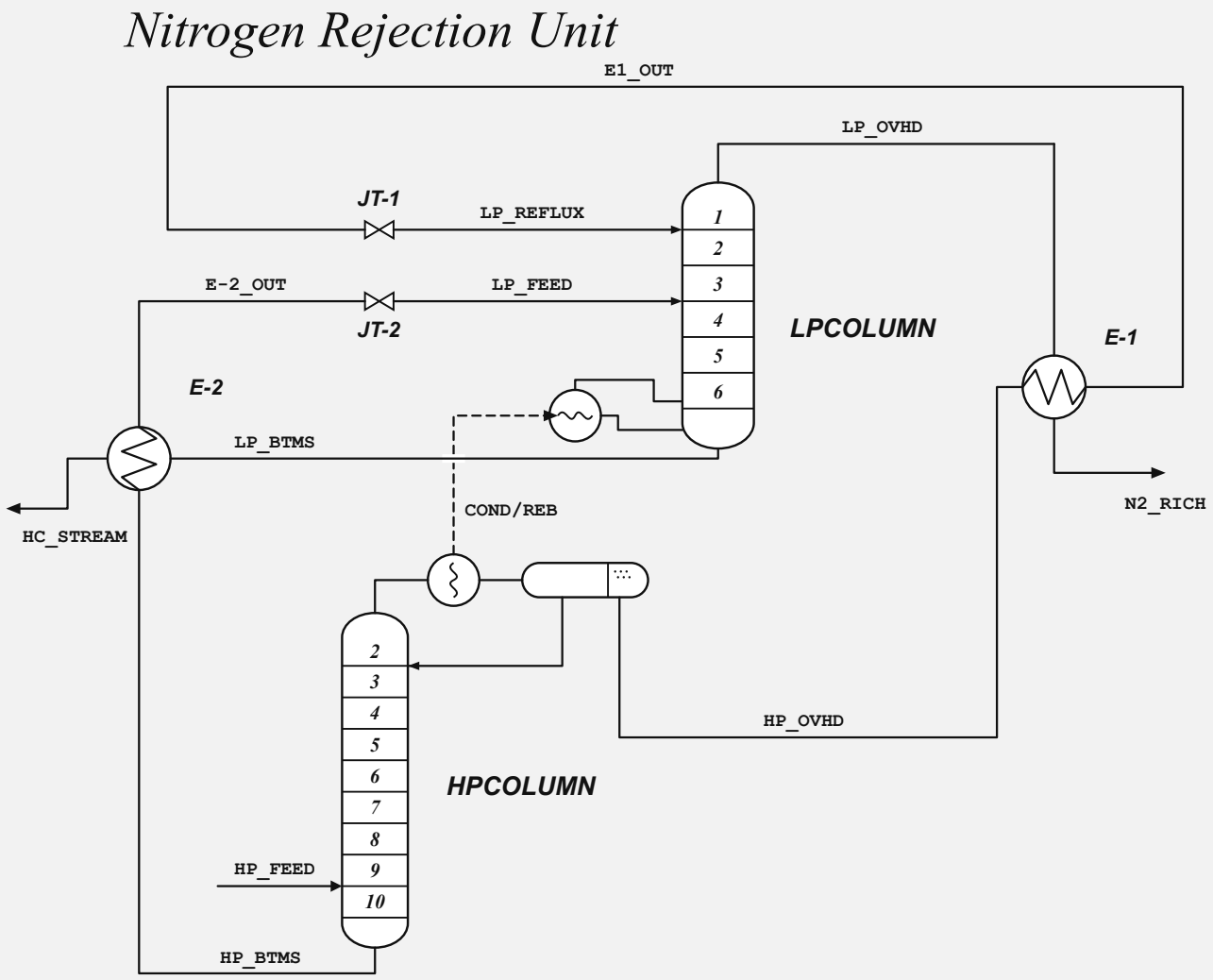
Nitrogen Rejection Unit

I took this example from a 35 year old Hysim (ancestor to Hysys) manual I still had lying around. It uses a two column process to produce high purity nitrogen and a natural gas stream. The feed has a large amount of nitrogen, apparently from using nitrogen for enhanced oil recovery.

The condenser of the high pressure column serves as the reboiler of the low pressure one.



Nitrogen Rich Natural Gas Feed

hp_feed

Label	Unit	B	V	L
q	Fraction	0.25665	1.00000	0.00000
t	degC	-137.22	-137.22	-137.22
p	kPa	2620.01	2620.01	2620.01
f	kmol/h	453.59	116.41	337.18
h	kJ/kmol	-10051.88	-6011.41	-11446.87
s	kJ/kmol-K	-75.04	-52.49	-82.83
hflow	W	-1266515.8	-194390.2	-1072125.5

x	nitrogen	0.54540	0.81713	0.45158
x	methane	0.41530	0.18214	0.49580
x	ethane	0.03470	7.181022e-4	0.04643
x	propane	3.600000e-3	7.511338e-6	4.840322e-3
x	isobutane	4.000000e-4	1.647643e-7	5.380448e-4
x	butane	3.000000e-4	5.737121e-8	4.035564e-4
x	isopentane	2.000000e-4	4.794169e-9	2.690492e-4
x	pentane	1.000000e-4	2.269798e-9	1.345246e-4

HPColumn

Stage	T degC	P kPa	V kmol/h	L kmol/h	Q W	Feeds kmol/h	Draws kmol/h
1	-152.66221	2551.06020		102.56306	-116843.52174		L 69.77965
2	-152.22765	2556.42279	172.34270	99.03332	0.00000		
3	-151.61478	2561.78538	168.81297	94.20800	0.00000		
4	-150.75114	2567.14796	163.98765	88.03159	0.00000		
5	-149.55527	2572.51055	157.81123	80.51597	0.00000		
6	-147.93287	2577.87314	150.29561	71.75837	0.00000		
7	-145.79774	2583.23573	141.53802	63.59662	0.00000		
8	-143.32817	2588.59832	133.37626	56.24607	0.00000		
9	-140.81695	2593.96091	126.02572	49.27998	0.00000		
10	-137.78862	2599.32350	119.05962		0.00000	453.59240	L 383.81275

hp_ovhd

Label	Unit	B	V	L
q	Fraction	1.00000	1.00000	0.00000
t	degC	-152.26	-152.26	-152.26
p	kPa	2551.06	2551.06	2551.06
f	kmol/h	102.56	102.56	0.00
h	kJ/kmol	-6532.45	-6532.45	-9028.88
s	kJ/kmol-K	-60.91	-60.91	-80.94
hflow	W	-186107.8	-186107.8	0.0
x	nitrogen	0.99000	0.99000	0.97610
x	methane	0.01000	0.01000	0.02390
x	ethane	3.592736e-13	3.592736e-13	6.799379e-12
x	propane	2.207548e-21	2.207548e-21	2.027373e-19
x	isobutane	2.088861e-22	2.088861e-22	4.780306e-20
x	butane	2.088861e-22	2.088861e-22	8.278312e-20
x	isopentane	2.088861e-22	2.088861e-22	2.772068e-19
x	pentane	2.088861e-22	2.088861e-22	3.548391e-19

hp_btms

Label	Unit	B	V	L
q	Fraction	0.00000	1.00000	0.00000
t	degC	-137.79	-137.79	-137.79
p	kPa	2599.32	2599.32	2599.32
f	kmol/h	383.81	0.00	383.81
h	kJ/kmol	-11344.85	-6021.30	-11344.85
s	kJ/kmol-K	-82.70	-52.59	-82.70
hflow	W	-1209527.6	0.0	-1209527.6
x	nitrogen	0.46457	0.82115	0.46457
x	methane	0.48899	0.17821	0.48899
x	ethane	0.04101	6.396665e-4	0.04101
x	propane	4.254503e-3	6.716941e-6	4.254503e-3
x	isobutane	4.727226e-4	1.491069e-7	4.727226e-4
x	butane	3.545419e-4	5.152879e-8	3.545419e-4
x	isopentane	2.363613e-4	4.372529e-9	2.363613e-4
x	pentane	1.181806e-4	2.067060e-9	1.181806e-4

Valves are assumed to be adiabatic, so giving pressure and the inlet enthalpy determines the temperature.

LP_Feed

Label	Unit	B	V	L
q	Fraction	0.37686	1.00000	0.00000
t	degC	-177.64	-177.64	-177.64
p	kPa	202.65	202.65	202.65
f	kmol/h	383.81	144.64	239.17
h	kJ/kmol	-11868.17	-6083.32	-15366.74
s	kJ/kmol-K	-82.08	-37.59	-108.99
hflow	W	-1265320.5	-244422.3	-1020898.2
x	nitrogen	0.46457	0.91524	0.19201
x	methane	0.48899	0.08476	0.73346
x	ethane	0.04101	4.498259e-6	0.06581
x	propane	4.254503e-3	2.511741e-9	6.827550e-3
x	isobutane	4.727226e-4	6.580056e-12	7.586168e-4
x	butane	3.545419e-4	7.641473e-13	5.689626e-4
x	isopentane	2.363613e-4	3.964284e-15	3.793084e-4
x	pentane	1.181806e-4	2.070913e-15	1.896542e-4

LPColumn

Stage	T degC	P kPa	V kmol/h	L kmol/h	Q W	Feeds kmol/h	Draws kmol/h

1	-189.09738	202.65000		77.53286	-1.36481	102.56306	V 246.98359
2	-187.27263	212.78250	221.95339	65.79464	0.00000		
3	-180.30525	222.91500	210.21518	299.14090	0.00000	383.81275	
4	-179.72580	233.04750	59.74868	300.25579	0.00000		
5	-178.43342	243.18000	60.86358	297.77266	0.00000		
6	-170.66571	253.31250	58.38045		116917.63324		L 239.39222

e1_out

Label	Unit	B	V	L
q	Fraction	0.00000	1.00000	0.00000
t	degC	-170.56	-170.56	-170.56
p	kPa	2547.61	2547.61	2547.61
f	kmol/h	102.56	0.00	102.56
h	kJ/kmol	-10556.36	-10556.36	-10556.36
s	kJ/kmol-K	-95.22	-95.22	-95.22
hflow	W	-300748.0	0.0	-300748.0
x	nitrogen	0.99000	0.99000	0.99000
x	methane	0.01000	0.01000	0.01000
x	ethane	3.592736e-13	3.592735e-13	3.592736e-13
x	propane	2.207548e-21	2.207548e-21	2.207548e-21
x	isobutane	2.088861e-22	2.088860e-22	2.088861e-22
x	butane	2.088861e-22	2.088860e-22	2.088861e-22
x	isopentane	2.088861e-22	2.088860e-22	2.088861e-22
x	pentane	2.088861e-22	2.088860e-22	2.088861e-22

Like E-2, a p-h flash is used to represent the valve

LP_Reflux

Label	Unit	B	V	L
q	Fraction	0.21635	1.00000	0.00000
t	degC	-189.33	-189.33	-189.33
p	kPa	202.65	202.65	202.65
f	kmol/h	102.56	22.19	80.37
h	kJ/kmol	-10556.36	-6358.46	-11715.35
s	kJ/kmol-K	-92.99	-43.51	-106.65
hflow	W	-300748.0	-39192.8	-261555.2
x	nitrogen	0.99000	0.99919	0.98746
x	methane	0.01000	8.059720e-4	0.01254
x	ethane	3.592736e-13	3.509411e-17	4.584547e-13
x	propane	2.207548e-21	1.417429e-27	2.817024e-21
x	isobutane	2.088861e-22	8.934244e-30	2.665569e-22

x	butane	2.088861e-22	1.371566e-30	2.665569e-22
x	isopentane	2.088861e-22	3.297398e-32	2.665569e-22
x	pentane	2.088861e-22	1.393428e-32	2.665569e-22

The outlet temperature is determined by heat balance.

N2_Rich

Label	Unit	B	V	L
q	Fraction	1.00000	1.00000	0.00000
t	degC	-133.85	-133.85	-133.85
p	kPa	199.20	199.20	199.20
f	kmol/h	246.98	246.98	0.00
h	kJ/kmol	-4681.72	-4681.72	-4681.72
s	kJ/kmol-K	-27.91	-27.91	-27.91
hflow	W	-321196.4	-321196.4	0.0
x	nitrogen	0.99772	0.99772	0.99772
x	methane	2.278465e-3	2.278465e-3	2.278465e-3
x	ethane	9.248717e-14	9.248717e-14	9.248717e-14
x	propane	1.824587e-21	1.824587e-21	1.824587e-21
x	isobutane	1.457587e-22	1.457587e-22	1.457587e-22
x	butane	1.457587e-22	1.457587e-22	1.457587e-22
x	isopentane	1.457587e-22	1.457587e-22	1.457587e-22
x	pentane	1.457587e-22	1.457587e-22	1.457587e-22

Again a heat balance is used to determine the temperature

HC_Stream

Label	Unit	B	V	L
q	Fraction	0.09322	1.00000	0.00000
t	degC	-164.49	-164.49	-164.49
p	kPa	249.87	249.87	249.87
f	kmol/h	239.39	22.32	217.08
h	kJ/kmol	-14399.52	-5893.26	-15274.01
s	kJ/kmol-K	-98.62	-33.93	-105.27
hflow	W	-957537.1	-36532.4	-921004.7
x	nitrogen	0.13962	0.71693	0.08027
x	methane	0.78592	0.28303	0.83761
x	ethane	0.06575	4.272655e-5	0.07250
x	propane	6.821160e-3	5.152590e-8	7.522402e-3
x	isobutane	7.579067e-4	2.132274e-10	8.358230e-4
x	butane	5.684300e-4	3.308701e-11	6.268673e-4

x	isopentane	3.789533e-4	3.210901e-13	4.179115e-4
x	pentane	1.894767e-4	1.827851e-13	2.089558e-4

The duty calculated for the condenser in the HPColumn is used as the heat for the LPColumn reboiler.

Cond_Reb_Duty	116.84352 kW

heat_values

Nitrogen kJ/kmol	**Methane kJ/kmol**	**Ethane kJ/kmol**	**Propane kJ/kmol**	**isoButane kJ/kmol**	**Butane kJ/kmol**	**isoPentane kJ/kmol**	**Pentane kJ/kmol**
0.00000	890360.00000	1559900.00000	2220000.00000	2868600.00000	2878500.00000	3529200.00000	3536100.00000

feed_HHV	492.75518 btu/scf

HC_HHV	932.66631 btu/scf