Steady State Process Description for Figure 4

Referring to Figure 4, the effluent stream from Reactor 1 (Stream 1) is sent through a valve, XV7, prior to being cooled in a series of heat exchanges in which energy is recovered. First it is cooled in Exchanger E-3, then in E-2 ad E-1 prior to being sent to the High-Pressure Separator, V-1. The vapor leaving V-1, is reheated in E-3 to 250°C and sent to the methanol reactor, R-2. In R-2, about 68% of the feed CO2 and 83% of the feed CO are converted to methanol. The heat generated by the exothermic reactions is transferred to the boiler feed water that surrounds the tubes in the reactor and produces steam at a pressure of 43.95 bar and 256°C. Note that the shell of the reactor is simulated as V-3 in the simx file. Boiler feed water, Stream 70, is sent to the shell side of R-2 through a valve (XV6) and steam is generated in the shell. This steam is throttled through a valve (XV1) and sent to the highpressure steam header operating at 42 bar. A small liquid stream, Stream 74, is taken from the shell side and is throttled through XV2 and sent to the boiler feed water system (operating at 42 bar). This "blowdown" stream is used to avoid the build-up of dissolved solids in the bfw on the shell side and is set and should be maintained at 50 kg/h.

The cooling of the process stream, Stream 3, in E-2 is performed by a circulating hot oil system. The hot oil, Steam 60, at 200°C flows through a valve, XV5, and enters the tube side of E-2, where it is heated to 400°C by heat exchange with the process stream. The process stream leaving E-2 is cooled to 220°C and is sent for final cooling in E-1. In E-1, cooling water at 30°C, Stream 40, is fed through a valve, XV4, to the tube side of E-1. The process stream leaving E-1, Stream 5, is cooled to 40°C while the cooling water return stream, Stream 42, is heated to 40°C. The values of all streams are given in Table 2.

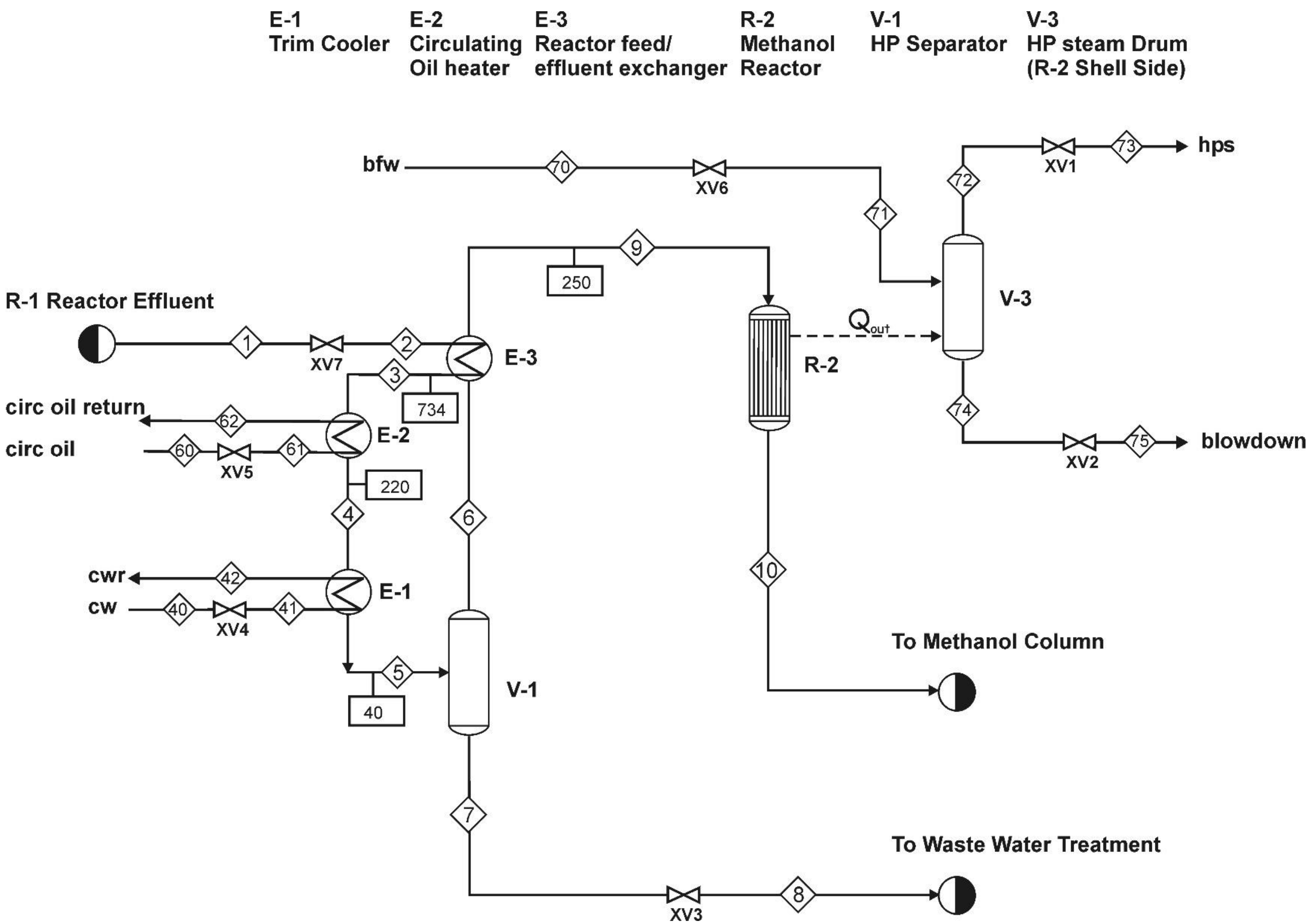
E-1
Trim Cooler
E-2
Circulating
Oil heater
E-3
Reactor feed/
effluent exchanger
R-2
Methanol
Reactor
V-1
HP Separator
V-3
HP steam Drum
(R-2 Shell Side)
bfw
70
XV6
71
72
XV1
73
hps
9
250
R-1 Reactor Effluent
1
XV7
2
E-3
3
734
Q_{out}
R-2
V-3
74
XV2
75
blowdown
circ oil return
62
E-2
circ oil
60
XV5
61
220
4
6
10
cwr
42
E-1
cw
40
XV4
41
To Methanol Column
5
40
V-1
7
To Waste Water Treatment
XV3
8

Figure 4: PFD

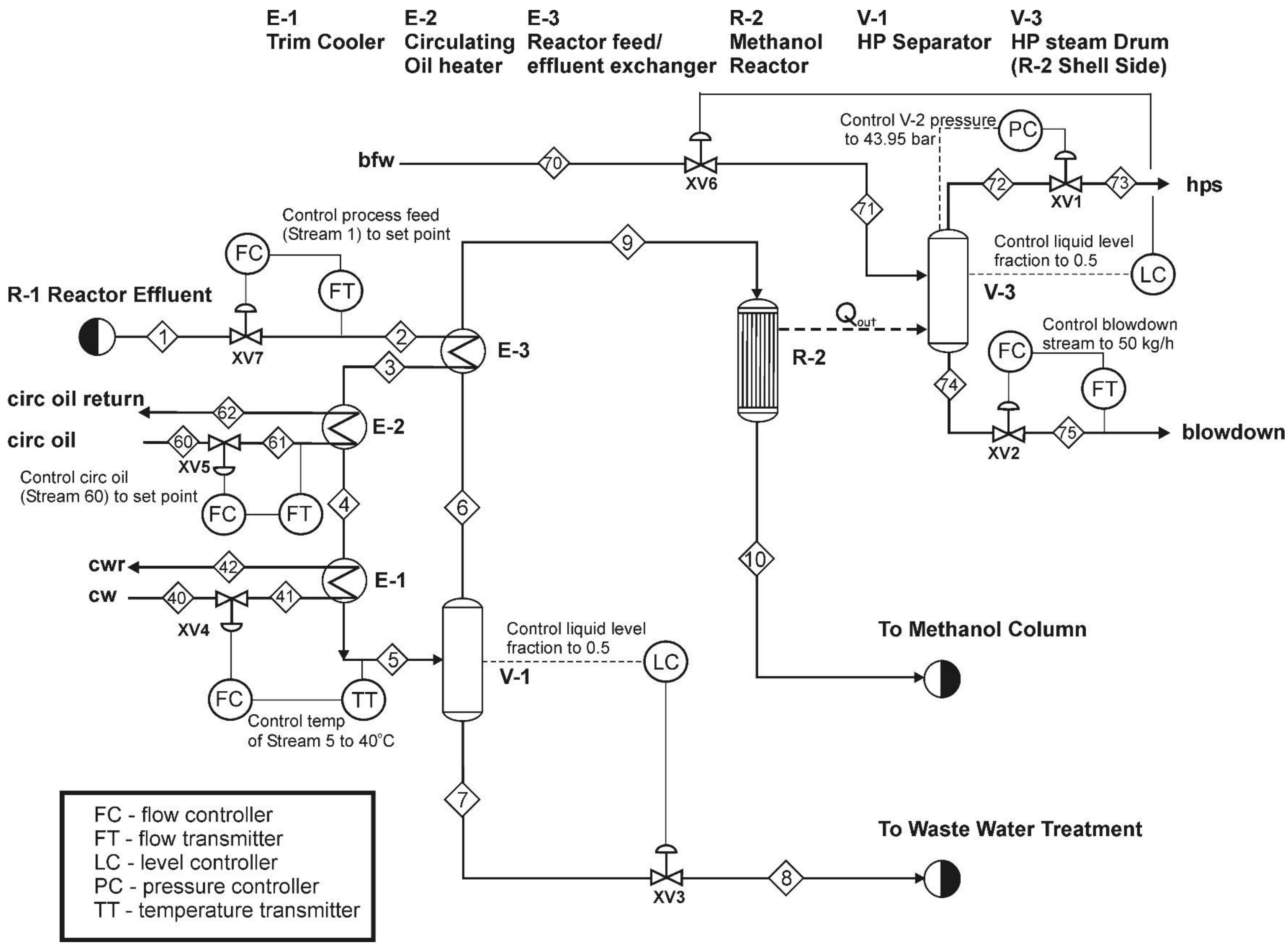

Figure 5: PFD for the dynamic simulation

Table 2: Flows for case corresponding to the PFD in Figure 4

Stream	1	2	3	4	5	6	7	8
Temp, °C	850	850	734	220	40	40	40	40
Pres, kPa	2900	2846	2811	2798	2784	2781	2793	2743
vf	1	1	1	1	0.6697	1	0	0
Mass flow, kg/h	52816	52816	52816	52816	52816	27947	24869	24869
Mole flow, kmol/h	4179.0	4179.0	4179.0	4179.0	4179.0	2798.5	1380.4	1380.4
Comp mole fraction								
hydrogen	0.4743	0.4743	0.4743	0.4743	0.4743	0.7083	2.4736E-06	2.4736E-06
nitrogen	0.0015	0.0015	0.0015	0.0015	0.0015	0.0022	4.7936E-10	4.7936E-10
oxygen	-	-	-	-	-	-	-	-
CO	0.0883	0.0883	0.0883	0.0883	0.0883	0.1318	1.8016E-07	1.8016E-07
CO_2	0.0543	0.0543	0.0543	0.0543	0.0543	0.0811	8.1927E-06	8.1927E-06
methane	0.0494	0.0494	0.0494	0.0494	0.0494	0.0737	2.1245E-08	2.1245E-08
ethane	-	-	-	-	-	-	-	-
methanol	-	-	-	-	-	-	-	-
water	0.3322	0.3322	0.3322	0.3322	0.3322	0.0028	9.9999E-01	9.9999E-01
circ oil	-	-	-	-	-	-	-	-
Stream	**9**	**10**	**40**	**41**	**42**	**60**	**61**	**62**
Temp, °C	250	257	30	30	40	200	200	400
Pres, kPa	2767	2717	400	300	265	1000	950	915
vf	1	1	0	0	0	0	0	0
Mass flow, kg/h	27947	27947	1994128	1994128	1994128	128659	128659	128659
Mole flow, kmol/h	2798.5	1875.9	110691.0	110691.0	110691.0	714.8	714.8	714.8
Comp mole fraction								
hydrogen	0.7083	0.4825	-				-	-
nitrogen	0.0022						-	-
oxygen	0.0000						-	-
CO	0.1318						-	-
CO_2	0.0811						-	-
methane	0.0737						-	-
ethane	0.0000						-	-
methanol	0.0000						-	-
water	0.0028						-	-
circ oil	-		-	-	-	1	1	1

Stream	70	71	72	73	74	75
Temp, °C	240	240	256	253	256	253
Pres, kPa	4800	4395	4395	4200	4491	4200
vf	0	0	1	0.9993	0	0.0079
Mass flow, kg/h	22305	22305	22255	22255	50	50
Mole flow, kmol/h	1238	1238	1235	1235	2.8	2.8
Comp mole fraction						
hydrogen	-	-	-	-	-	-
nitrogen	-	-	-	-	-	-
oxygen	-	-	-	-	-	-
CO	-	-	-	-	-	-
CO_2	-	-	-	-	-	-
methane	-	-	-	-	-	-
ethane	-	-	-	-	-	-
methanol	-	-	-	-	-	-
water	1	1	1	1	1	1
circ oil	-	-	-	-	-	-

3.3 Deliverables

The scenario that you are to consider is one in which the feed rate (Stream 1) is cut to approximately half its design value (26,000 kg/h) for a period of 12 hours. This scenario occurs when an upstream control valve (not shown in Figure 4 or 5) must be replaced while still running the process. During this scenario, the circulating oil stream should remain at its design flow.

The following deliverables are required for completion of Part 3:

(i) Provide a simx file for the converged **dynamic** simulation at design (basecase) conditions corresponding to the conditions given in Table 2, obtained after steps a-g have been completed. Also provide Plots 1-4 (defined in Part (iii) below) for the dynamic simulation for a period of 1 hour demonstrating that all variables are constant.

(ii) Using the dynamic simulation, set the flow controller on Stream 1 to 26,000 kg/h and perform a dynamic simulation. For this scenario, you should track the time trends of the following four sets of variables using 4 separate trend plots.

Variable Set (I) - S70.W, S73.W, V3.Level - **Plot 1**

Variable Set (II) - S1.W, S40.W, S9.W, and R2.Duty - **Plot 2**

Variable Set (III) - S42.T, S72.T, S9.T, S10.T, S5.T - **Plot 3**

Variable Set (IV) - Moles of methanol in Stream 10, Moles of Water in Stream 10, S10.F - **Plot 4**

Note that the return temperature of the cooling water must never exceed 45°C and the temperature in the reactor must never exceed 300°C. If either or both of these issues occur, you should adjust the set point(s) on the appropriate controller(s) to alleviate the problem(s).

(iii) For each Plot, the starting point (t =0) should be the time at which the step change in Stream 1 is made. You should provide copies (screen shots) for the design case and the reduced flow case for the time period 0 - 60 mins. You should also provide a screen shot for the reduced flow case for the time period 0 -12 hours (0 - 720 min).

(iv) A brief but informative write up, not to exceed 600 words, must be submitted that describes the behavior and response of the system to the change in feed flowrate. If any of the variables in the plots do not reach steady state within the 12-hour period of the test, comment on why you think this occurs. Can such oscillations/unsteady state conditions be overcome in the 12-h period that you consider?

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