CHBE 470 -- Control Design Problem
Maleic Anhydride Plant
Homework #9 - Due November 30, 2007

The feed preparation and reaction section of a Maleic Anhydride plant is shown in the following sketch. In this exercise, you will design controls for this plant. You may **not** add any equipment.

In this section of the plant, n-butane is vaporized by steam, then combined with air and sent to a fixed-bed reactor. The desired main reaction is $C_4H_{10} + 7/2\ O_2 \rightarrow C_4H_2O_3 + 4H_2O$. A few notes:

- Air/hydrocarbon mixtures require tight control of the reactor composition to keep the mixture from reaching explosive limits. This is a safety issue.
- In this reaction, the desired value of the analyzer A1 is 1.8% n-butane. More air moves the mixture away from the explosive limit. For tight composition control, it's best to manipulate the smaller flow.
- Suction throttling is a common way of controlling the flow through a compressor that has a fixed-speed motor driver.
- You can assume that the feed is pure n-butane.

Questions:

a. In the table on Page 4, state how many degrees of freedom there are and determine which variables should be controlled.
b. Specify the failure position for each control valve in Figure 1. On a separate page, state your reasoning for setting the failure position of each valve.
c. Sketch the “loop pairing” for a control design in Figure 1 using single-loop feedback (e.g. PID) control.
d. Steam pressure P4 fluctuates, and P1 cannot be controlled as tightly as desired (even though you're an amazing control engineer). Sketch an improved control design with cascades in Figure 2.

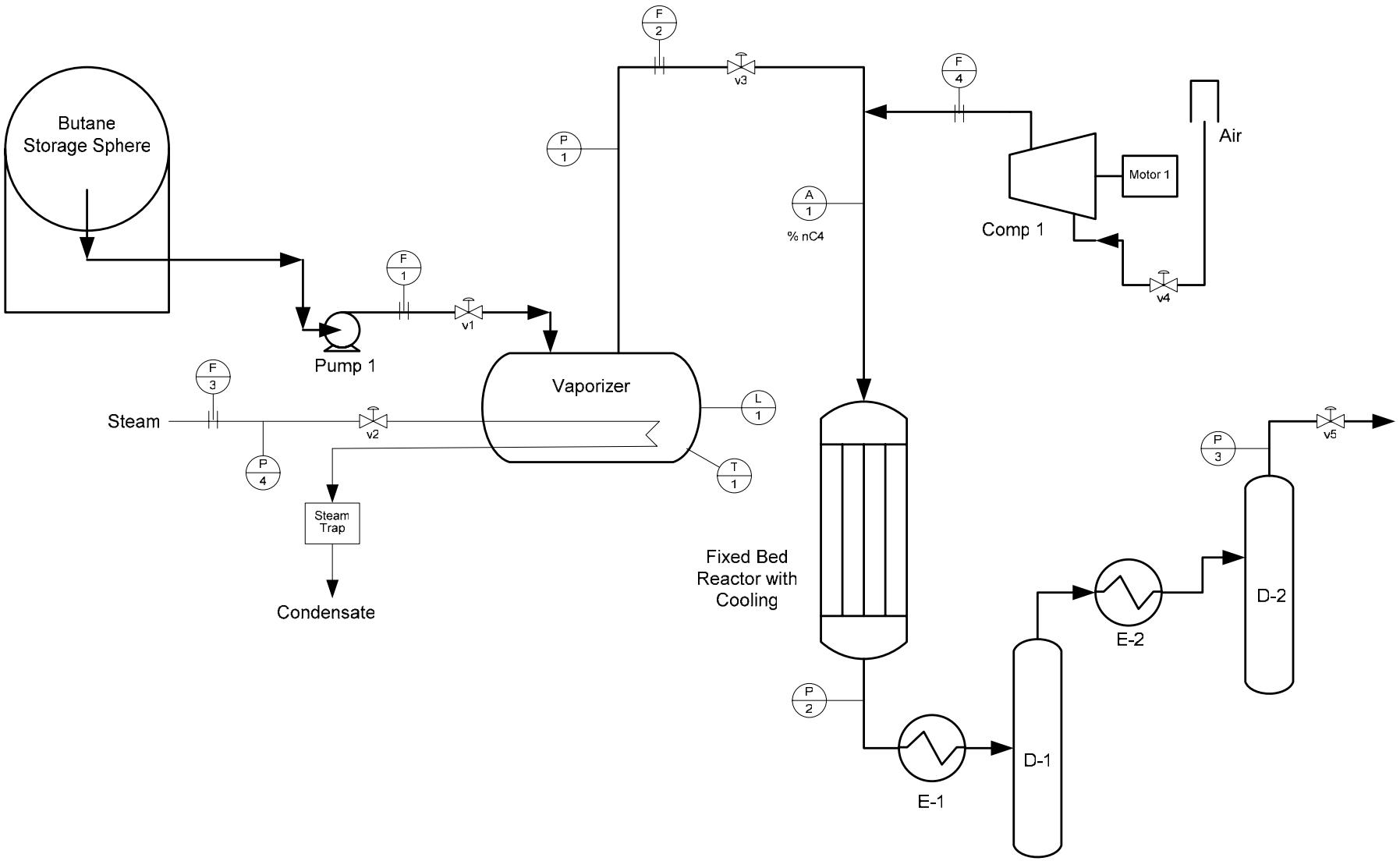

Figure 1. Maleic Anhydride control design: Use only single-loop controllers and show valve failure positions.

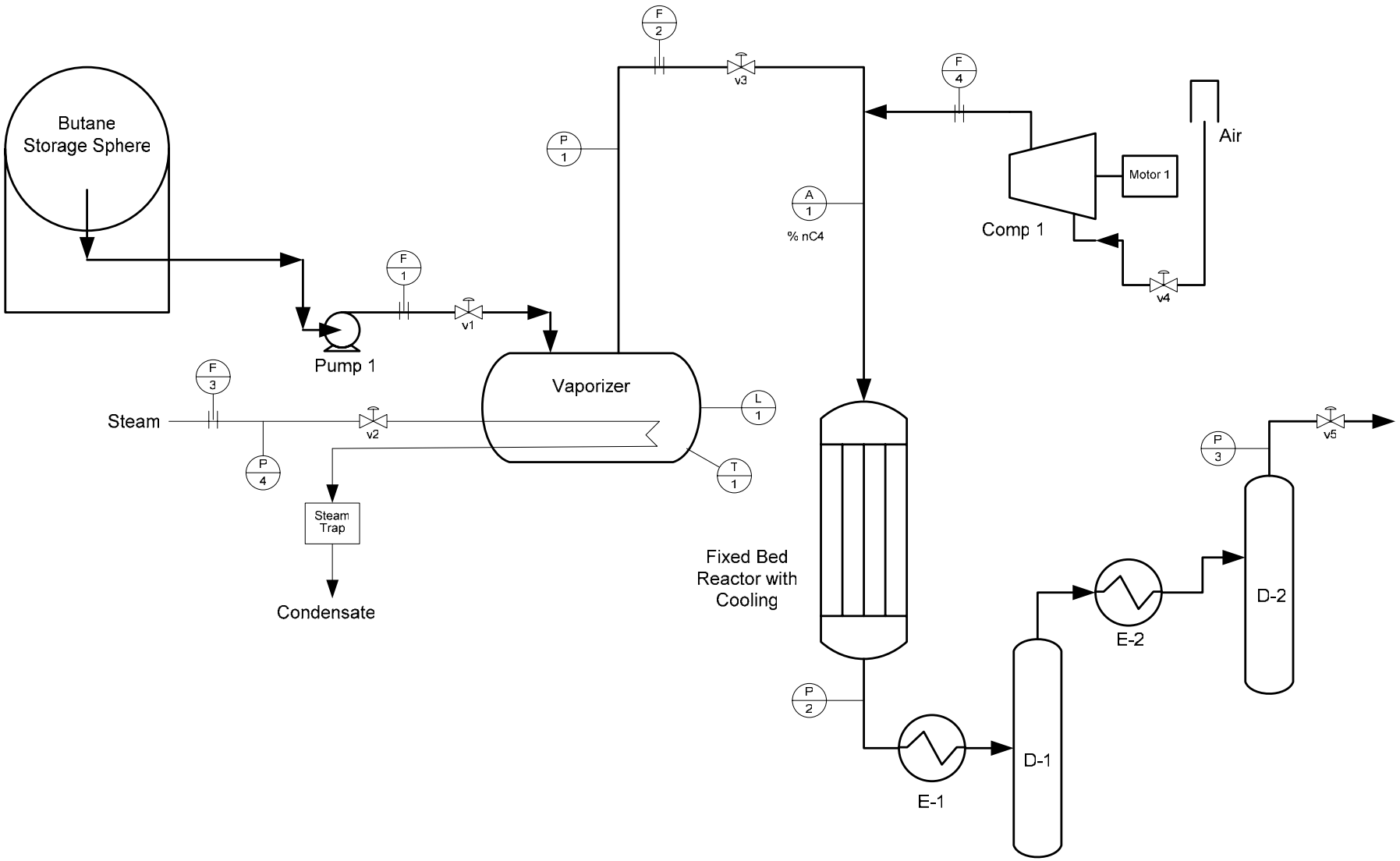

Figure 2. Maleic Anhydride control design: Show feedback control strategy including cascades where they improve overall control.

Degrees of Freedom: _____

Control Objective
1. Safety
2. Environmental protection
3. Equipment protection
4. Smooth operation
5. Product quality
6. Profit
7. Monitoring and Diagnosis