Solutions for Tutorial 2
Control Objectives & Benefits

2.1 We will invest lots of effort understanding process dynamics between "inputs" and "outputs". The outputs are key variables that we want to maintain at or near specified desired values. The inputs belong to two distinct categories.

1. Manipulated variables that we adjust to achieve desired process behavior
2. Disturbance variables whose values vary due to changes in other processes and the surrounding environment.

If no disturbances occurred, there would be little need for process control; however, disturbances occur to essentially every process.

Let's look at an example process and find some examples of variables in each of the two categories. The process in Figure 2.1 vaporizes liquid butane and mixes the vapor with compressed air. The mixture flows to a packed bed reactor.

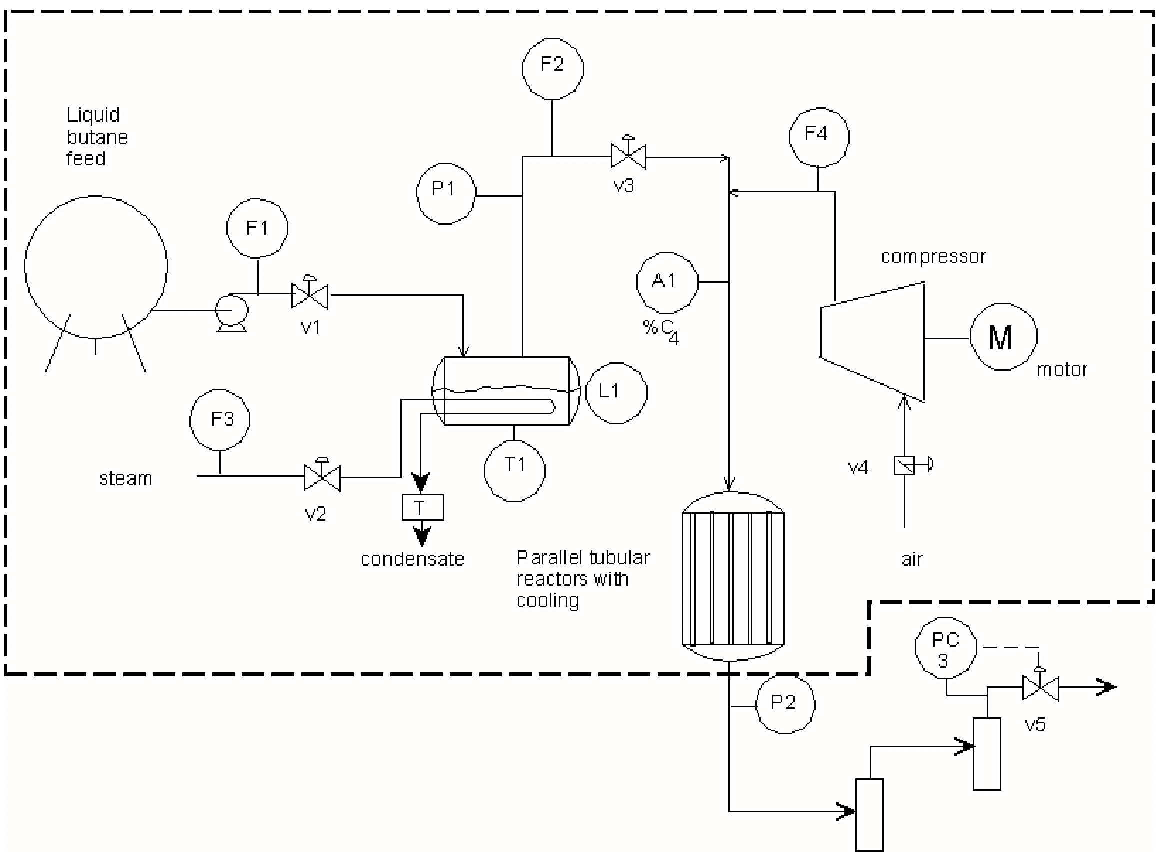


Figure 2.1

a. Identify at least three controlled variables, which must be measured.

b. Identify at least one manipulated variable for each of the controlled variables. Hint: these must be valves.

c. Identify at least three disturbance variables. (These do not have to be measured.) For each, determine which controlled variable(s) are influenced, i.e., disturbed.

a. Controlled variables

1. Pressure of the vaporizer (P1), which is important for safety.

2. Liquid level in the vaporizer (L1), which influences the amount vaporized. It should not overflow the vessel or drain empty.

3. The percentage of butane in the mixed stream (A1), which is important if we are to avoid an explosive concentration!

b. Manipulated variables

1. The vapor lease from the vaporizer (v3). This has a causal relationship with the pressure and can be adjusted to control P1.

2. The flow of liquid butane from storage to the vaporizer (v1). This has a causal relationship with the liquid level and can be adjusted to control L1.

3. The flow of air is affected by the valve in the compressor suction, v4. This has a causal relationship with the flow of air and the mixture composition and can be adjusted to control A1.

c. Disturbances

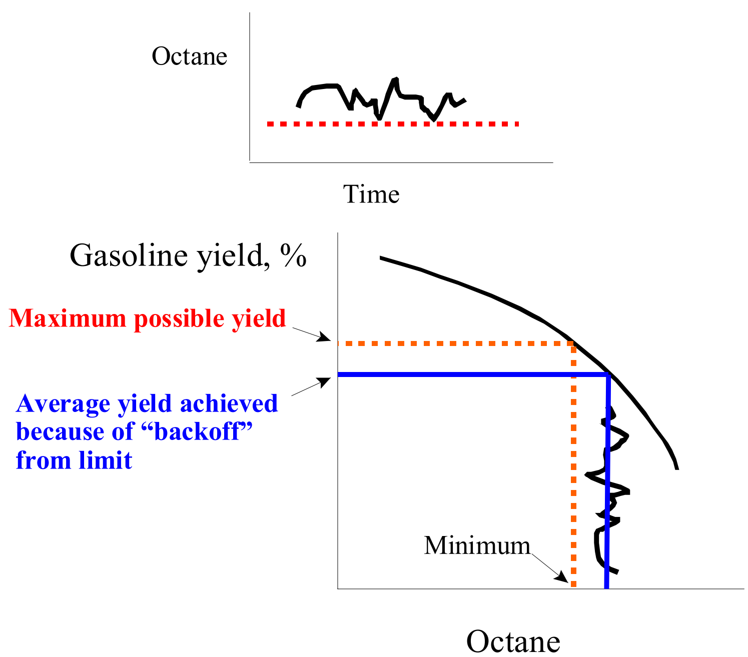
1. Steam pressure that influences the heat transfer in the vaporizer and affects P1 and L1.

2. Air temperature that influences the compressor performance and affects the mixture composition.

3. Pressure downstream from the reactor that influences the flows of butane and air.

2.2 Economic benefits: Discuss the economic benefits achieved by reducing the variability (and, in some cases changing the average value) of the key controlled variable for the situations in the following.

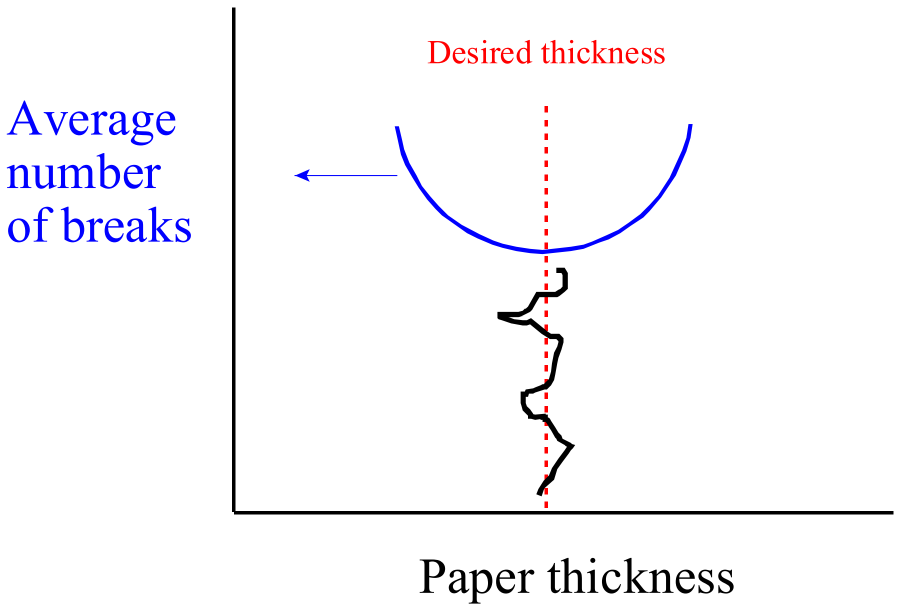
a. Crude oil is distilled, and one segment of the oil is converted in a chemical reactor to make gasoline. The reactor can be operated over a range of temperatures; as the temperature is increased, the octane of the gasoline increases, but the yield of gasoline decreases because of increased by-products of lower value. (It's not really *this* simple, but the description captures the essence of the challenge.) The customer cannot determine small changes in octane. You are responsible for the reactor operation. Is there a benefit for tight temperature control of the packed bed reactor? How would you determine the correct temperature value?



In this situation, the customer cannot distinguish small changes from the minimum octane when driving their automobiles. Therefore, this small deviation in product quality is acceptable. However, the variability in the octane results in a lower average yield of gasoline and a higher yield of lower valued byproducts. Tight control of reactor temperature will reduce the variability in octane and allow a higher average yield of valuable gasoline. The average temperature can be selected to achieve acceptable octane for all production within the variation.

Note that the goal here is to reduce variability and adjust the average value to increase profit.

b. You are working at a company that produces large roles of paper sold to newspaper printers. Your client has many potential suppliers for this paper. Your customer can calibrate the printing machines, but after they have been calibrated, changes to paper thickness can cause costly paper breaks in the printing machines. Discuss the importance of variance to your customer, what your product quality goal would be. Is this concept different from the situation in part (a) of this question?



In this situation, the average paper thickness is not extremely important, so long as the customers can calibrate their machinery. However, after you and the customers have agreed on a thickness, essentially any variation is harmful, because it increases the likelihood of paper breaks. The customers lose production time, paper, and perhaps, the workers are subject to hazardous conditions. If you do not supply consistent thickness, the customer will find another supplier.

Therefore, the goal here is to retain the agreed average and reduce the variability to the minimum achievable.

2.3 The data in Figure 2.3 reports experience in a blending of Residuum and more expensive Gas Oil to produce a product with upper and lower viscosity specifications. The "before" data represents manual operation by plant personnel. The "after" data represents feedback control using a computer and a on-stream viscosity analyzer. Discuss the performance and the source of benefits.

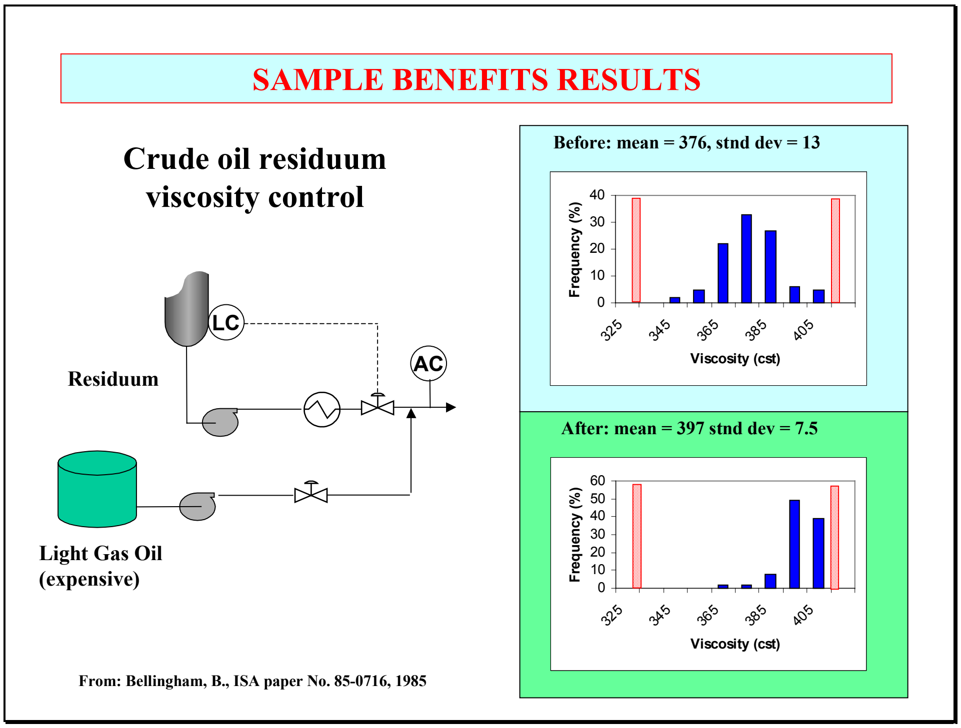


Figure 2.3

The "before data is typical of poor control for a variable with upper and lower bounds. The nature tendency is to maintain the variable close to the "middle" of the range. This approach allows for the greatest variability without exceeding either bound. However, the average viscosity is low, which indicates that excessive expensive Gas Oil has been consumed and cannot be sold at a higher price.

After analyzer feedback has been implemented, the variability has been reduced, which allows the average value of the viscosity to be increased without exceeding the bounds. Increased profit results from less use of Gas Oil in this lower value product, which can be sold at a higher value.

