GRAPHICAL TECHNIQUES FOR DIRECT-RECYCLE STRATEGIES.

Process industries use tremendous amounts of material resources. Mismanagement of resources leads to the depletion of natural resources and poses many economic, social and ecological challenges. Therefore process industries now started material conservation initiatives to enhance market competitiveness and sustainability.

Strategies adopted for material conservation

1. Segregation
2. mixing
3. recycle / reuse
4. material substitution
5. reaction alteration
6. process modification.

Segregation: Segregation refers to avoiding mixing of streams. This prevents loss of driving force of streams and enhances performance of process units (separators) and can also provide composition levels that allow the streams to be recycled directly to the process.

Recycle: Recycle refers to the utilization of a process stream in the process unit (a sink)

Reuse: Reapplication of the stream for the original intent.

Direct recycle: Streams are rerouted without the installation of new devices. It is low cost strategy involves only pumping & piping and in some cases even be achieved without the need for additional pumping or piping.

First a targeting technique will be described to identify bounds on minimum usage of fresh resources and minimum discharge of wastes thro' recycle/reuse. Next, a systematic procedure is presented to implement the specific stream rerouting that attains the identified target.

Consider a process with a number of process sources (e.g., process streams, wastes) that can be considered for possible recycle and replacement of the fresh material/reduction of waste discharge. Each source i, has a given flow rate, W_i, and a given composition of a targeted species, y_i. Available for service is a fresh resource that can be purchased to supplement the use of process sources in sinks. The sinks are process units such as reactors, separators etc. Each sink j requires a feed whose flow rate, G_j^{in}, and an inlet composition of targeted species z_j^{in} must satisfy certain bounds on their values.

The objective is to develop a graphical procedure that determine the target for minimum usage of fresh resource, maximum ~~usage of~~ material reuse and minimum discharge of waste. The design questions to be answered include

(1) Should the stream be segregated or split? To how many fractions? What should be the flow rate of each split.

(2) Should the streams be mixed? To what extent?

(3) What should be the optimum feed entering each sink? What should be its composition

(4) What is the minimum amount of fresh resource to be used.

(5) What is the minimum discharge of unused process sources.

Source-sink Mapping diagram and Lever-arm rules.

The source sink mapping diagram is a visualization tool that can be used to device useful recycle rules. As mentioned in the problem statement there are bounds on flow rate and composition entering each sink. These bounds are described by the following constraints

$$G_j^{min} \leq G_j^{in} \leq G_j^{max} \quad \text{where } j = 1, 2, \ldots N_{sinks}.$$

Where G_j^{min} and G_j^{max} are given lower and upper bounds on admissible flow rate to unit j.

$$z_j^{min} \leq z_j^{in} \leq z_j^{max} \quad \text{where } j = 1, 2, \ldots N_{sinks}$$

Where z_j^{min} and z_j^{max} are given lower and upper bounds on admissible compositions to unit j.

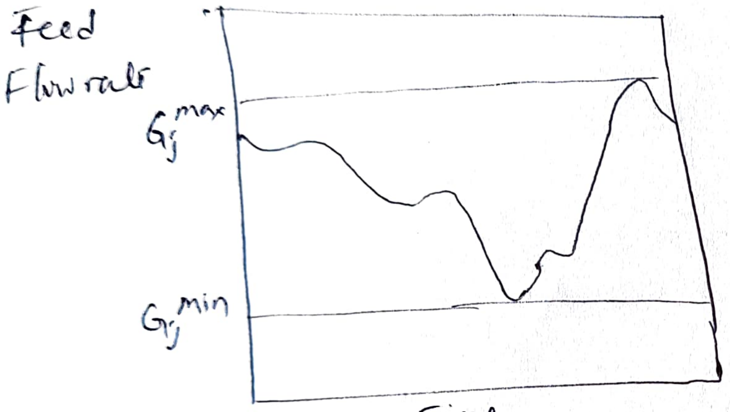
The flow rate and composition bounds for each sink can be determined based on several considerations such as

(1) Technical considerations (e.g. manufacturer specifications operable composition ranges to avoid scaling, corrosion build up etc. Operable flow rate ranges such as weeping / flooding flow rates.

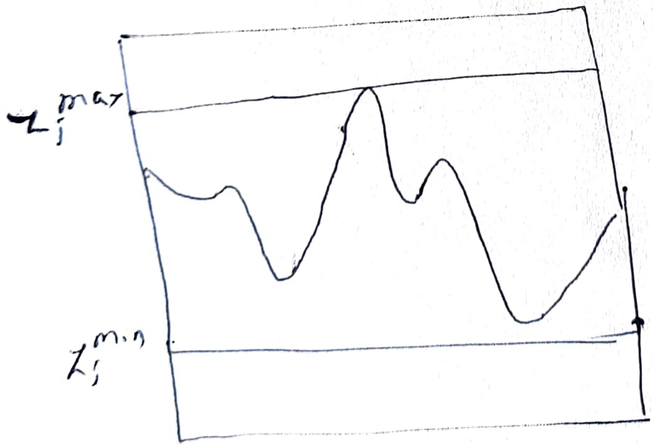
(2) safety: To stay away from explosion

③ physical (e.g. saturation limits)

④ Monitoring: These bounds can also be determined from historical data of operating the unit which are typically available through the process information monitoring systems. Figures illustrate the bounding of feed flow rate and composition for sink j based on monitored data for which the sink has performed acceptably.

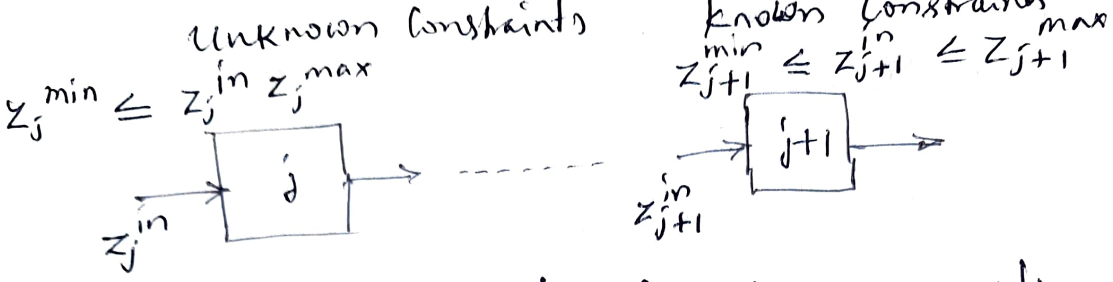


Bounding feed flow rate based on monitored data



Bounding Feed Composition based on monitored data.

(5) Constraint propagation.



Constraint propagation to determine composition bounds.

In some cases, the constraints on a sink (j) are based on critical constraints for another unit ($j+1$). Using a process model to relate the inlets of units j and $j+1$, we can derive the constraints for unit j based on those for unit $j+1$. Suppose, the constraints for units $j+1$ are given by

$$0.06 \le z_{j+1}^{in} \le 0.08$$

and the process model relating the inlet compositions to units j and $j+1$ can be expressed as

$$z_{j+1}^{in} = 2 z_j^{in}$$

$\therefore$ the bounds for the unit j are calculated

$$0.03 \le z_j^{in} \le 0.04$$