What is process Integration.

A chemical process is an integrated system of interconnected units and streams. Proper understanding and solution of process problems should not be limited to symptoms of the problem but should identify the root causes of these problems by treating the process as a whole. Therefore integration of process is a critical element in designing and operating cost effective and sustainable processes. "Process integration is a holistic approach to process design, retrofitting, and operation which emphasizes the unity of the process

Process integration involves the following activities.

1. Task identification.

The first step in synthesis is to clearly express the goal we are aiming to achieve and describe it as an actionable task

e.g. ① quality enhancement to reach a specific composition of product

② waste water reduction in AN case study

③ Stabilizing middle and heavy distillates in coal pyrolysis

● The task may be quantified with extreme performance (e.g. minimum waste water discharge)

a Specific value (e.g. 50% reduction in wastewater)

or as a multivariable function (relationship betn extent of waste water ~~content~~ reduction & pollutant content.

② Targeting :

Targeting refers to the identification of performance benchmarks ahead of detailed design

③ Generation of Alternatives (Process Synthesis)

④ Selection of Alternatives

⑤ Analysis of Selected Alternatives (Process Analysis)

~~This evaluation~~ Process analysis techniques can be employed to Evaluate the selected alternative. This evaluation may include prediction of performance, techno-economic analysis, safety review, environmental impact assessment.

Categories of process integration.

Energy integration

Energy integration is a systematic methodology that provides a fundamental understanding of energy utilization within the process and employs this understanding to identifying performance targets and optimizing the ~~generation~~ heat recovery and Energy utility systems.

Mass integration

Mass integration is a systematic methodology that provides a fundamental understanding of the global flow of mass within the process and employs this understanding in identifying performance targets and optimizing the generation and routing of species throughout the process.

Targeting for Minimum Discharge of waste.

To illustrate the concept of overall mass targeting, let us start by considering the objective of minimizing the discharge of a waste.

Consider the case when it is desired to determi[ne] the target for minimizing the load of a discharged species (e.g., pollutants in effluents)

(F) - Quantity of the targeted species in streams Entering the process

(G) - Net amt. of ~~large~~ targeted species produced through chemical reaction.

(D) - depletion of targeted species due to chemical reaction. leaks, emissions and other losses,

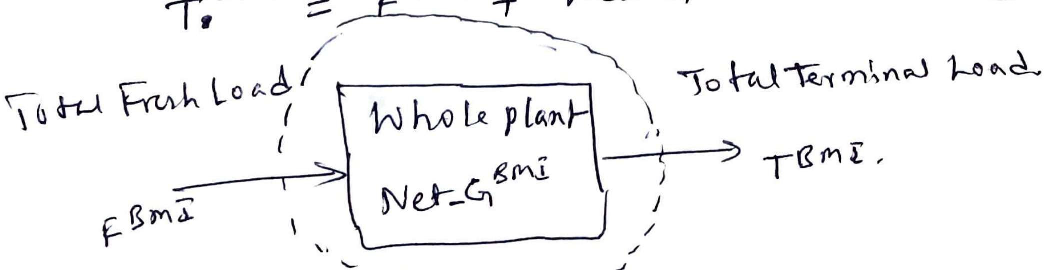
The net generation ~~of~~ (Net-G) of a targeted species

$$\text{Net\_G} = G - D. \qquad \text{———} \quad (1)$$

Let T - Terminal discharge used to refer to the load of ~~~~ the targeted species in waste streams.

An overall material balance on the targeted species before mass integration changes.

$$T^{BMI} = F^{BMI} + \text{Net\_G}^{BMI} \qquad \text{———} \quad (2)$$



In order to reduce the terminal discharge of the targeted species, the two terms on RHS of Equation (1) are to be reduced.

case 1 When the net generation is independent of stream recycle and adjustments in fresh feed

A two step method is used to identify the minimum discharge target.

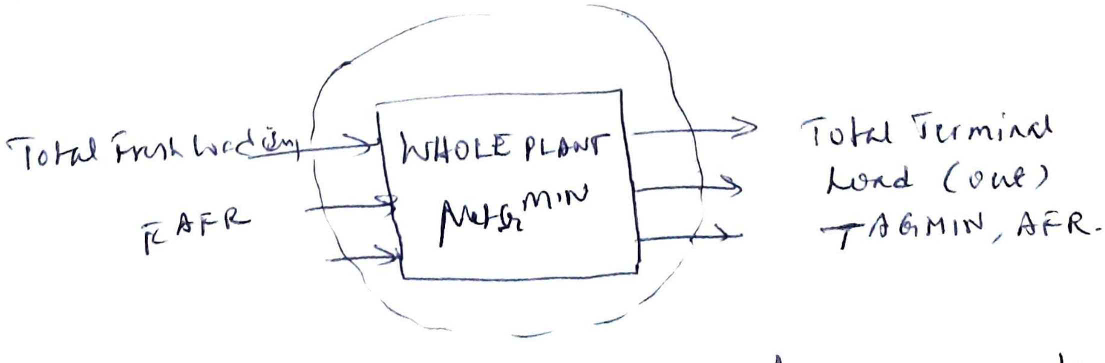
First step:
The net generation of targeted species is minimized. The net generation can be described in terms of the process design and operating variables that are allowed to be modified. Once, the net generation has been minimized, we can calculate the terminal discharge load after generation minimization (TAGMIN) thro' overall mass balance

$$TAGMIN = F^{BMS} + Net\_G^{MIN} \qquad ⓷$$

Second step.
The fresh usage in the process is minimized by adjusting design and operating variables that influence the fresh usage.

$$F = f(\text{manipulated design variables, manipulated operating variables}) \qquad (3a)$$

Equation 3a can be minimized to identify the minimum load of the targeted species in the fresh feeds after reduction (IAFR)



The terminal load after minimization of net generation and reduction in fresh feed

$$TAGMIN, AFR = F^{AFR} + Net\_G^{MIN} \qquad (3b)$$

~~Finally~~ It is impossible to recover the targeted species from the terminal streams and render the recovered species in a condition which enables its use in place of the targeted species in the fresh feed. Clearly, the higher the recovery and recycle to replace the fresh ~~feed~~ load, the lower the net use and lower the terminal discharge. Consequently in order to minimize the terminal discharge of the targeted species, we should recycle the maximum amount from terminal streams to replace the fresh feed.

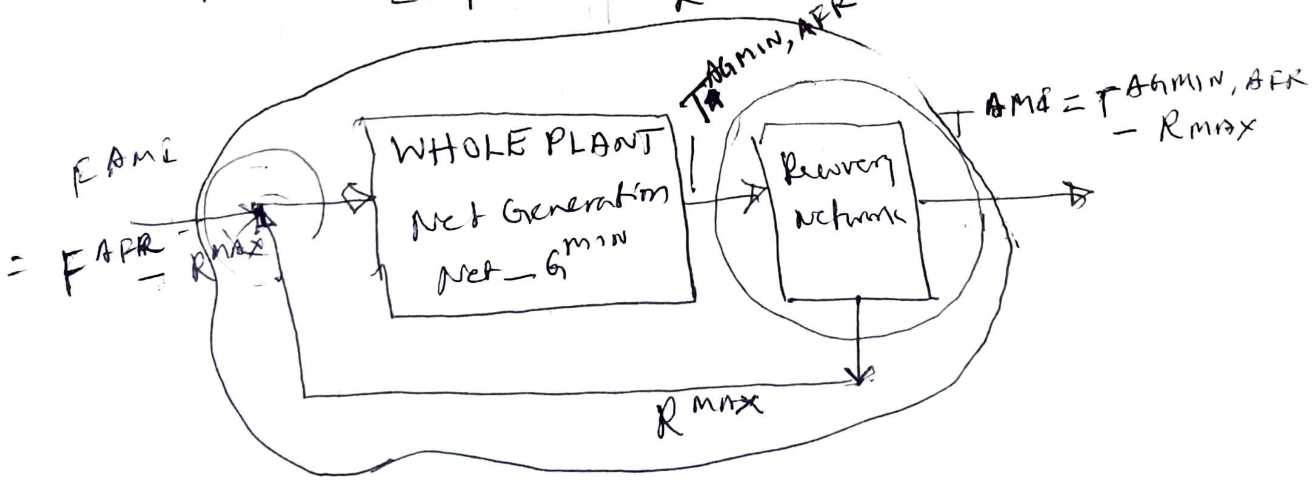
The maximum recyclable load of the targeted species is the lowest of the two loads, the fresh and the terminal.

$$R^{MAX} = \text{argmin}\left(F^{AFR}, T^{AGMIN, AFR}\right) \quad — (4)$$

argmin - Lowest value in the set of loads (fresh and terminal loads)

As a result of recycle, the fresh load after mass integration becomes

$$F^{AMI} = F^{AFR} - R^{MAX} \quad — (5)$$



∴ The target for minimum discharge of targeted species after mass integration (T^{AMI}) can be calculated through overall material balance after mass integration

~~T^{AMI}~~ Input = Output ~~$T^{AGMIN, AFR}$~~ ~~R^{MAX}~~

Output = Input + Generation

$$T^{AMI} = F^{AMI} + Net\_G^{MIN} \quad — (6)$$

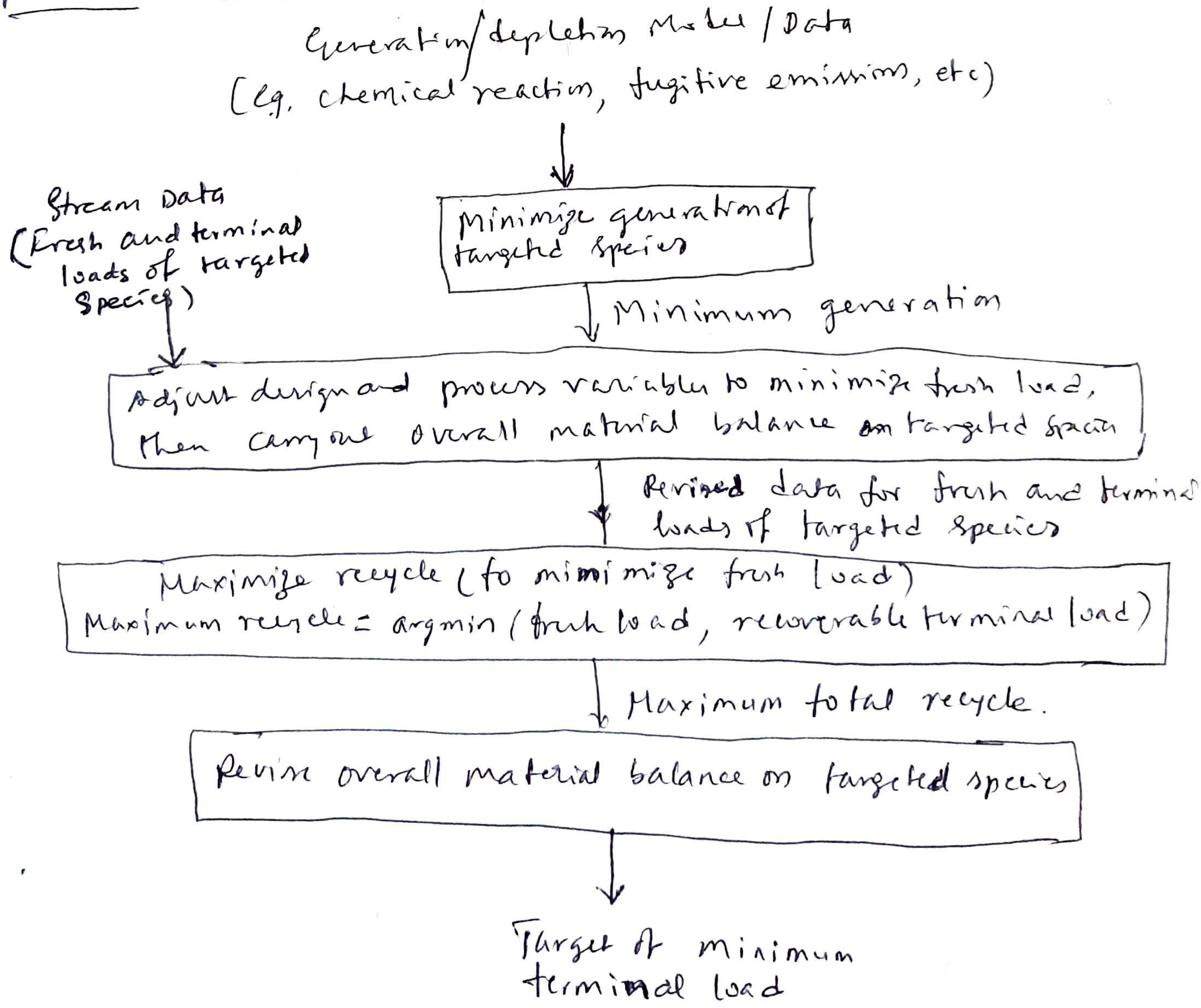
Alternatively, the target ~~species~~ for minimum discharge can be calculated from a material balance around the recovery and recycle system.

$$T^{AME} = T^{AGMIN,AER} - R^{MAX} \qquad (2.7)$$

~~Procedure for ident~~

It is worth mentioning that in the spirit of targeting, it is not necessary to determine the type or techno-economic details of the recovery system. The objective is to determine the target for minimum load to be discharged from the plant. Later, we discuss how the various alternatives are systematically screened with the objective of meeting this target at minimum cost.

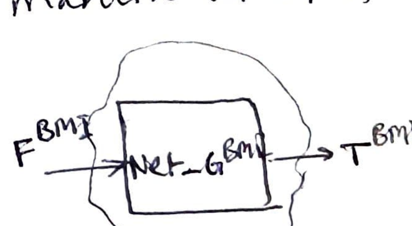
Procedure for identifying minimum waste discharge



The foregoing procedure can be summarized by the flow chart shown in fig. First, the generation and depletion information are gathered as data or models. These include information on the depletion or generation of ~~data~~ the targeted species thro' chemical reactions loss of species thro' emissions and leaks etc. Data are also collected on the amount of targeted species in fresh feeds entering the process or terminal streams leaving the process. The net generation, is first minimized. Then, the fresh feed of the targeted species is minimized by adjusting design and operating variables. Next, a recovery system is placed to recover maximum recyclable load (the lower of the fresh & terminal loads). Hence the fresh feed is minimized as maximum recycle is used to replace fresh feed. Finally, the overall material balance is used to calculate the target for minimum waste discharge.

Targeting for minimum purchase of fresh material utilities

Case; Targeting minimum fresh usage of material utilities (water, solvent, additives etc)



The overall material balance

Output = Input + Generation

$$F^{BMI} + Net\_G^{BMI} = T^{BMI}$$

$$\text{or } F^{BMI} = T^{BMI} - Net\_G^{BMI} \qquad (8)$$

The key difference is that the net generation is maximized as opposed to minimised in the case of waste discharge)