XII. MATERIAL BALANCE, PLANT EVALUATION AND MODELING

Simple mass balance for a processing plant often leads to a reasonable estimation of the performances of individual unit operations as well as overall plant. In these computations often the mass flow rates and the assay values of various material streams are used. However, in many instances, the streams may not be sampled and therefore the assay data may not be available. Also, the mass flow rate values are not measured for many intermediate streams of a flowsheet. However, with the available data and measurement of minimum additional data may be sufficient for detailed mass balancing and plant evaluation. This is illustrated with an example below. In the Figure 9, the stream name is followed by its identification number.

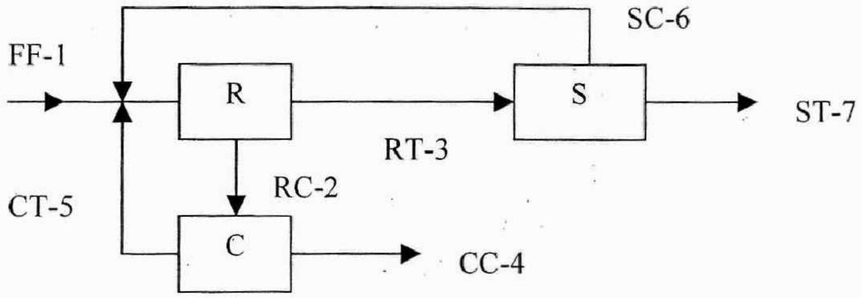

Fig. 9 : A typical circuit for processing in Mineral Processing Plant

In the above Figure, the fresh material is fed to process operation R (stream name FF, ID no 1). The valuable stream from R (RC-2) is further processed in operation C for quality improvement, while the gangue stream from R (RT-3) is processed in operation S for recovering any remaining valuable before discarding. The gangue stream from C (CT-5) is likely to have some valuable and is fed back to process R along with stream FF. The valuable from C (CC-4) is good quality material and is the valuable product of the circuit. Similarly, the valuable stream of operation S (SC-6) is fed back to R and the gangue stream from S (ST-7) indeed has little or no valuable and is the other product (waste) of the circuit.

Usually, the solids mass flow rates of the fresh feed (stream 1) and valuable product (stream 4) are measured. The valuable content (assay) of various streams are also measured. If 'F' denotes the mass flow rate of solids and 'a' denotes the assay value then, say the following data are available (the calculated data are marked so in the Table):

Stream No. →	1	2	3	4	5	6	7
Mass flow rate (F, tph)	100	56.94 (calc)	104.21 (calc)	25.82	31.12 (calc)	30.03 (calc)	74.18 (calc)
Assay (a, %)	8.2	16.9	3.6	26.3	9.1	7.8	1.9 (calc)

For the overall circuit the following mass balance may be written:

F1 = F4 + F7	for the total mass conservation and
F1 x a1 = F4 x a4 + F7 x a7	for the valuable mass conservation

With the data from the Table, the above two equations may be solved to obtain the mass flow rate and assay of the waste product stream (F7=74.18 tph and a7 = 1.9%). Thus, overall plant performance may be computed as:

Yield = (mass flow rate of valuable stream)/(mass flow rate of feed stream) = 25.82%

Recovery = (valuable flow rate in valuable stream)/(valuable flow rate in feed stream)
= (F4 x a4)/(F1 x a1) = 82.81%

Similarly, mass balance around process C gives:

F2 = F4 + F5 and F2 x a2 = F4 x a4 + F5 x a5

Solving the above two one gets F2 = 56.94 tph and F5 = 31.12 tph.

So, process C has the following performance indicators:

Yield = 45.35% and Recovery = 70.57%.

Mass balance around process S:

F3 = F7 + F6 and F3 x a3 = F7 x a7 + F6 x a6

Solving them for F3 and F6 one gets F3 = 104.21 tph and F6 = 30.03 tph.

Yield = 28.82% and Recovery = 62.44%.

Now, the values around process R are known and its performance may be computed:

Yield = (56.94)/(100 + 30.03 + 31.12) = 35.33%
Recovery = (16.9 x 56.94)/(8.2 x 100 + 30.03 x 7.8 + 31.12 x 9.1) = 71.95%

Thus, the evaluation of individual unit operations and overall plant performance may be done through mass balance techniques.

Modeling Concepts:

The operations in mineral processing can be broadly divided into three categories, namely, transformation, separation and de-watering. The units that change the characteristics of the material are known as transformation units. For example, the crushing and grinding operations change the particle size of the material. The separation units are those that separate the minerals making use of the differences in their properties. For example, flotation unit separates on the basis of hydrophobicity of the mineral surfaces and heavy media cyclones separate the heavy minerals from the lighter ones. Filters and dryers separate the water from the solids. Even thickeners and fine screens are often considered de-watering units for one of the product streams is predominantly water.

This simple classification of operations is effectively exploited in modeling the unit operations and thereby simulating the plant performance. The model of a transformation unit should be able to compute the product characteristics given the details of the feed material along with machine parameters. It may be noted that all transformation units must have only one feed stream and one product stream. Thus in generic form the model of such units may be represented in the vector-matrix form:

$$\mathbf{P} = \mathbf{T}\,\mathbf{F} \qquad \text{........................(15)}$$

Where, **P** and **F** are vectors describing the product and the feed characteristics and **T** is a transformation matrix that defines how the characteristics of the feed are converted into that of the product stream. The determination of this matrix, however, is quite involved and requires in-depth analysis of the mechanisms of the process.

The separation units on the other hand must have a minimum of two product streams. The model of these units should be able to describe the various product streams from the given description of the feed stream. This is achieved by making use of efficiency vectors. The efficiency of transfer of material of certain type to a particular product stream may be expressed in a similar vector-matrix form:

$$\mathbf{P1} = \mathbf{E1}\,\mathbf{F} \qquad \text{..........................(16)}$$

$$\mathbf{P2} = \mathbf{E2}\,\mathbf{F} \qquad \text{..........................(17)}$$

etc., where, **P1, P2 ...** are vectors describing different product streams, **F** is the vector describing feed stream and **E1, E2** are efficiency matrices signifying transfer to a specific stream. It may be noted that the efficiency matrices are all diagonal matrices and they must add up to 100% (Identity matrix). Thus, for a two-product separation process **E1 = I - E2**. Again, the estimation of these efficiency matrices depends on the science of the process. The approach for the estimation of these matrices varies widely with each process and may be deeply involved task. However, such a description of the calculated product streams are then passed to a simulation tool as feed to a subsequent operation in the plant flowsheet. A complete simulation of the entire flowsheet could thus be made possible.