



# Mass Balance Methodology

An Online Continuing Education Course for Engineers

**Course Number: M-2078**

**Credit: 2 Hours / 2 PDH / 2 CPD**

# Mass Balance Methodology

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## Introduction

This course provides a methodology for solving mass balance problems in steady-state\* continuous process systems. Mass balances are the important first step in essentially all chemical engineering problems for determining the flow rates, compositions and other key characteristics for each process stream. This information serves as the basis for essentially all subsequent process design calculations.

The course begins with two elementary examples:

- Simple blending of two process streams to form one stream.
- Simple separation of one process stream into two streams.

Additional complexity is then introduced in a stepwise fashion:

- Multiple streams
- Multiple process steps.
- Bypass streams

Finally, chemical reactions are considered:

- Mass balances are required for each atom (stoichiometry)
- Excess reactants & incomplete reactions

The following methodology is used in each mass balance problem:

1. A process flow diagram (PFD) is drawn with each stream identified and given a unique label. Process “envelopes” are defined and indicated on the process flow diagram.
2. A table is constructed. All of the known characteristics for each stream are included in the table.
3. Mass balance equations are developed for the boundaries of each process envelope. This often results in a system of linear equations.
4. The system of equations is solved using algebraic and/or matrix methods.

**Course Outcome** -- At the completion of this course, the student will be able to set up and solve relatively complex mass balance problems for steady-state continuous process systems.



Stream #	1	2	3
Number of Red Balls	$R_1$	$R_2$	$R_3$
Number of Green Balls	$G_1$	$G_2$	$G_3$
Number of Yellow Balls	$Y_1$	$Y_2$	$Y_3$
Number of Balls (Total)	$T_1$	$T_2$	$T_3$

The next step is to **set up a system of equations** that describes the mathematical inter-relationships between the process variables:

$$R_1 + R_2 = R_3$$

$$G_1 + G_2 = G_3$$

$$Y_1 + Y_2 = Y_3$$

$$T_1 + T_2 = T_3$$

$$R_1 + G_1 + Y_1 = T_1$$

$$R_2 + G_2 + Y_2 = T_2$$

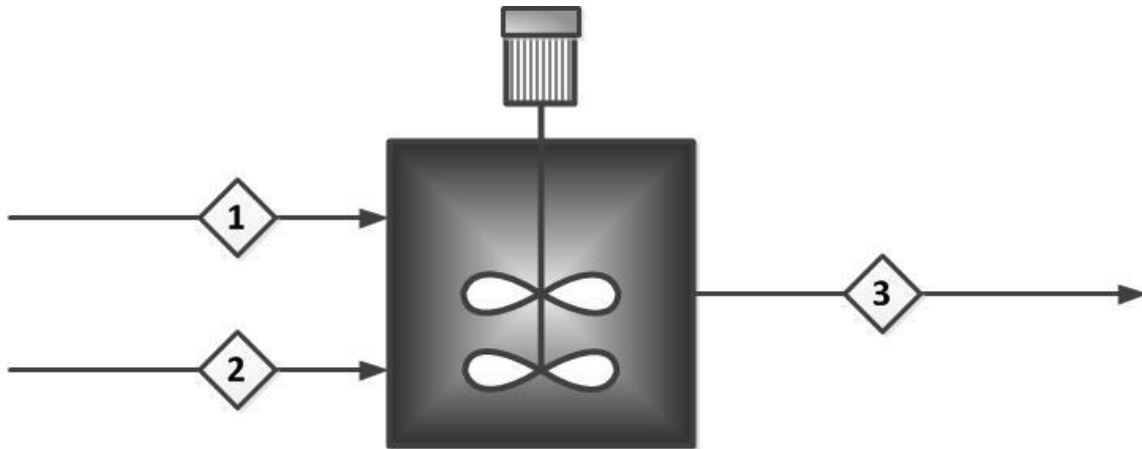
$$R_3 + G_3 + Y_3 = T_3$$

The final step is to **solve the system of equations**. Material and energy balance problems can result in large systems of linear equations, which can be solved using a variety of algebraic and/or matrix techniques. Some of these techniques are demonstrated in this course.

### **Example Problem 1:**

We will begin by solving a simple blending problem using this methodology. Two streams are fed continuously to a blender. A third stream continuously exits the blender. Stream #1 contains three red balls, an unknown number of green balls, and zero yellow balls. Stream #2 contains four green balls and a total of ten balls. The blended stream (Stream #3) contains five red balls, six green balls and an unknown number of yellow balls. Calculate the total flows and compositions for each stream.

**Step 1: Draw a process flow diagram:**



**Step 2: Set up a table:**

Stream #	1	2	3
Number of Red Balls	3	$R_2$	5
Number of Green Balls	$G_1$	4	6
Number of Yellow Balls	0	$Y_2$	$Y_3$
Number of Balls (Total)	$T_1$	10	$T_3$

**Step 3: Set up a system of equations:**

Equation 1:  $3 + R_2 = 5$   
Equation 2:  $G_1 + 4 = 6$   
Equation 3:  $0 + Y_2 = Y_3$   
Equation 4:  $T_1 + 10 = T_3$   
Equation 5:  $3 + G_1 + 0 = T_1$   
Equation 6:  $R_2 + 4 + Y_2 = 10$   
Equation 7:  $5 + 6 + Y_3 = T_3$

**Step 4: Solve the system of equations:**

Special methods are not always needed to solve a system of equations. Begin by looking for equations that contain only one unknown variable. In this case, the solution to  $R_2$  is readily obtained by solving Equation 1;  $G_1$  is obtained by solving Equation 2.  $Y_2$  can then be obtained by substituting the solution for  $R_2$  into Equation 6.  $Y_3$  is obtained by substituting the solution for  $Y_2$  into Equation 3. This substitution process is repeated until solutions to all of the variables are found:

Stream #	1	2	3
Number of Red Balls			5
Number			6
Number			4
Number			15

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**Example Problem 2:**

Let's solve another blending problem. The component are given for each stream that would be available for blending.

(pages ÷ 100) of each type of information

Two streams are fed continuously into a blender. Stream #1 contains 20% red balls per hour. Stream #2 contains 30% red balls (Stream #3) contains 38% red balls. Find the component flows and total flows for each stream.

exits the blender. Stream #1 is 1000 balls per hour. The blended stream contains 25% red balls. Find the component

In this problem, more than enough information has been provided to get a unique solution. Sometimes it is necessary to assume a basis of design, such as a feed rate for one of the streams.