Thermal Equilibrium Diagrams (Phase Diagrams)

Equilibrium may be defined as a state of balance of stability. When a metal solidifies, equilibrium will occur under conditions of **slow cooling** where the reduction in temperature is small in relation to the time elapsed (gone). To achieve equilibrium it would be necessary, at every stage of cooling, to give the alloy elements **time to diffuse** (mix through on another) which would lead to a state that each grain of metal would have the same composition throughout. Complete diffusion seldom takes place in casting because solidification usually takes place before diffusion is complete.

The Lever Rule

The equilibrium diagram for a solid solution alloy that we have just been dealing with contains two different phases, liquid and solid solutions. Between the liquidus and solidus lines these two phases exist together in equilibrium and hence the area between the curves is known as the two phase region. If a horizontal line is drawn through the two phase region, such a line is called a tie line. We see a tie line drawn in this equilibrium diagram. The lever rule may be introduced by considering the simple see-saw. For the see-saw to be balanced, i.e. in equilibrium, without movement up or down on either side, **(weight W1) (distance X1) = (weight W2) (distance X2).**

This is the lever rule and in metallurgy the horizontal constant temperature tie-line represents the see-saw with the fulcrum (hinge point) at the alloy composition under consideration. Therefore if we take the diagram for the (**Copper-Nickel**) alloy as in figure 5, and we take the composition of **60%** Copper and **40%** Nickel the lever rule will apply like this.

[Weight of solid solution of composition (q) / Weight of liquid of composition (m)]= bm / qb

Ratio = bm / qb

There are a number of different types of thermal equilibrium diagrams

1. Two metals completely soluble in each other in both liquid and solid states.
2. Two metals completely soluble in each other in the liquid but not in the solid state (**Eutectic alloy**).
3. Two metals completely soluble in each other in the liquid and partially soluble in the solid state.
4. Iron / Carbon equilibrium diagram.

1. Two metals completely soluble in each other in both liquid and solid states

Instead of dealing with several different cooling curves for any alloy, a quicker graph has been created using the various arrest points of all the alloys. When these points are marked on a graph and joined up we get a thermal equilibrium diagram which looks like this in figure below.

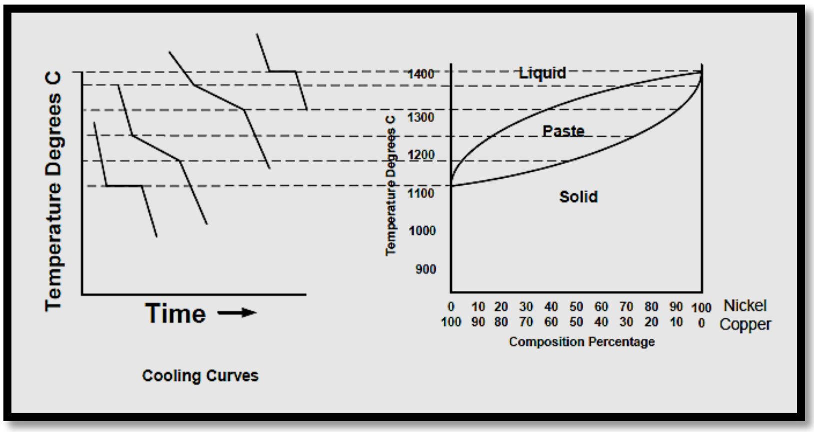

Figure 1. Creating a thermal equilibrium diagram.

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As you can see there are three areas the **liquid state**, the **solid state** and the **pasty state** (consists of a solid phase and a liquid phase). A very important point to note is that the line joining all the points where the liquid begins to solidify is known as the **Liquidus line** while the line joining all the points where solidification is just complete is known as the **Solidus line**.

If we want to find out what temperature **60%** Copper is fully solidifies at in an alloy of Copper and Nickel. Firstly we need the thermal equilibrium diagram for the alloy of Copper and Tin. This is the thermal equilibrium diagram for the alloy of Copper and Nickel. In order to find what temperature **60%** copper solidifies at we simply draw a vertical line from **60%** copper until it hits the solidus line and at this is the point where **60%** Copper has fully solidified.

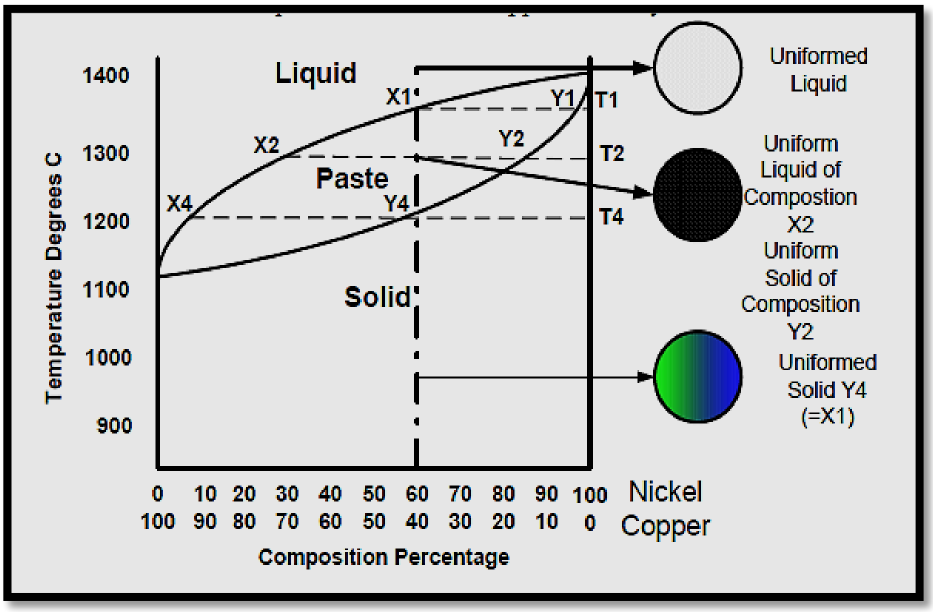

Figure 2. Nickel-Copper thermal equilibrium diagram.