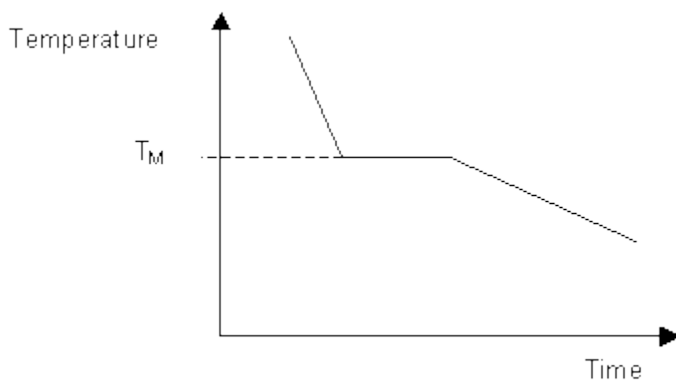


# Interpretation of cooling curves

The melting temperature of any pure material (a one-component system) at constant pressure is a single unique temperature. The liquid and solid phases exist together in equilibrium only at this temperature. When cooled, the temperature of the molten material will steadily decrease until the melting point is reached.

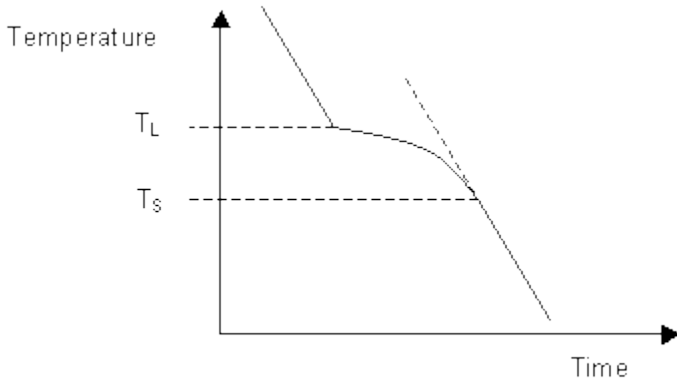
At this point the material will start to crystallise, leading to the evolution of latent heat at the solid liquid interface, maintaining a constant temperature across the material. Once solidification is complete, steady cooling resumes. The arrest in cooling during solidification allows the melting point of the material to be identified on a time-temperature curve.



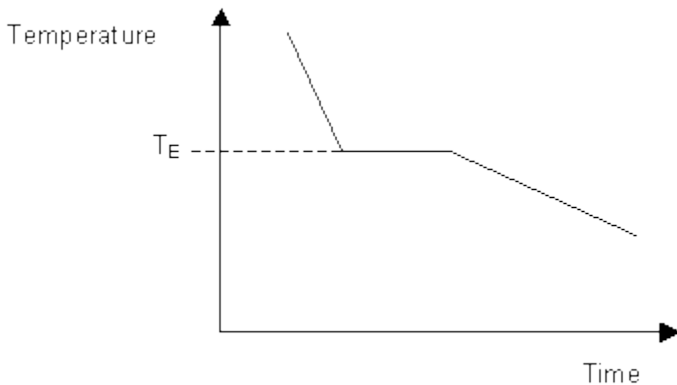
Most systems consisting of two or more components exhibit a temperature range over which the solid and liquid phases are in equilibrium. Instead of a single melting temperature, the system now has two different temperatures, the liquidus temperature and the solidus temperature which are needed to describe the change from liquid to solid.

The liquidus temperature is the temperature above which the system is entirely liquid, and the solidus is the temperature below which the system is completely solid. Between these two points the liquid and solid phases are in equilibrium. When the liquidus temperature is reached, solidification begins and there is a reduction in cooling rate caused by latent heat evolution and a consequent reduction in the gradient of the cooling curve.

Upon the completion of solidification the cooling rate alters again allowing the temperature of the solidus to be determined. As can be seen on the diagram below, these changes in gradient allow the liquidus temperature  $T_L$ , and the solidus temperature  $T_S$  to be identified.

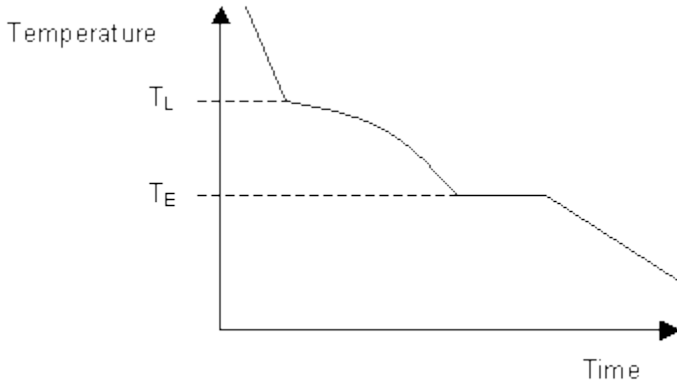


When cooling a material of eutectic composition, solidification of the whole sample takes place at a single temperature. This results in a cooling curve similar in shape to that of a single-component system with the system solidifying at its eutectic temperature.



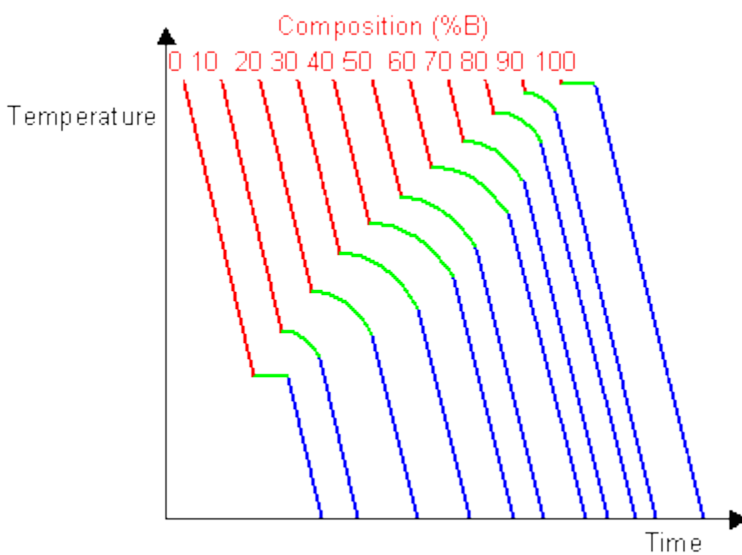
When solidifying hypoeutectic or hypereutectic alloys, the first solid to form is a single phase which has a composition different to that of the liquid. This causes the liquid composition to approach that of the eutectic as cooling occurs. Once the liquid reaches the eutectic temperature it will have the eutectic composition and will freeze at that temperature to form a solid eutectic mixture of two phases.

Formation of the eutectic causes the system to cease cooling until solidification is complete. The resulting cooling curve shows the two stages of solidification with a section of reduced gradient where a single phase is solidifying and a plateau where eutectic is solidifying.

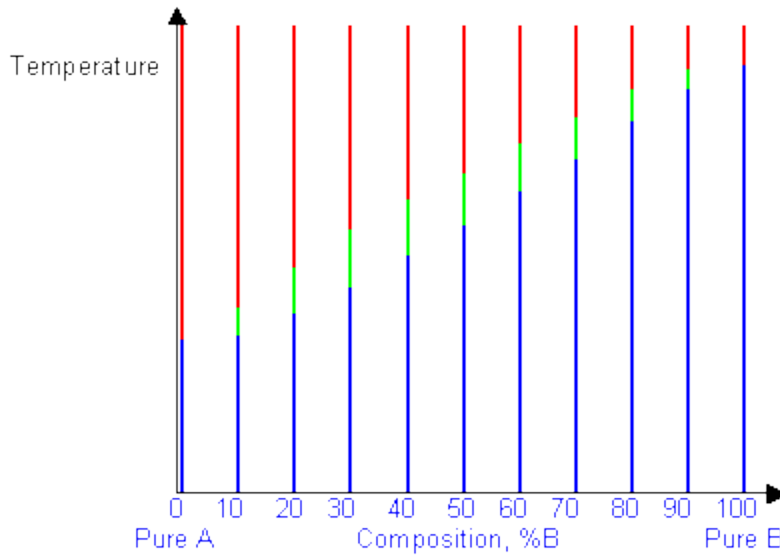


By taking a series of cooling curves for the same system over a range of compositions the liquidus and solidus temperatures for each composition can be determined allowing the solidus and liquidus to be mapped to determine the phase diagram.

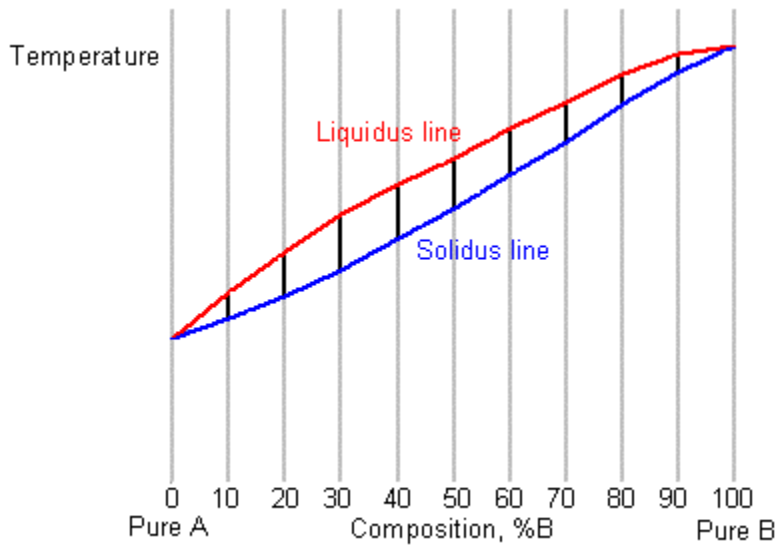
Below are cooling curves for the same system recorded for different compositions and then displaced along the time axis. The red regions indicate where the material is liquid, the blue regions indicate where the material is solid and the green regions indicate where the solid and liquid phases are in equilibrium.



By removing the time axis from the curves and replacing it with composition, the cooling curves indicate the temperatures of the solidus and liquidus for a given composition.



This allows the solidus and liquidus to be plotted to produce the phase diagram:



Source: <http://www.doitpoms.ac.uk/tlplib/phase-diagrams/cooling.php>