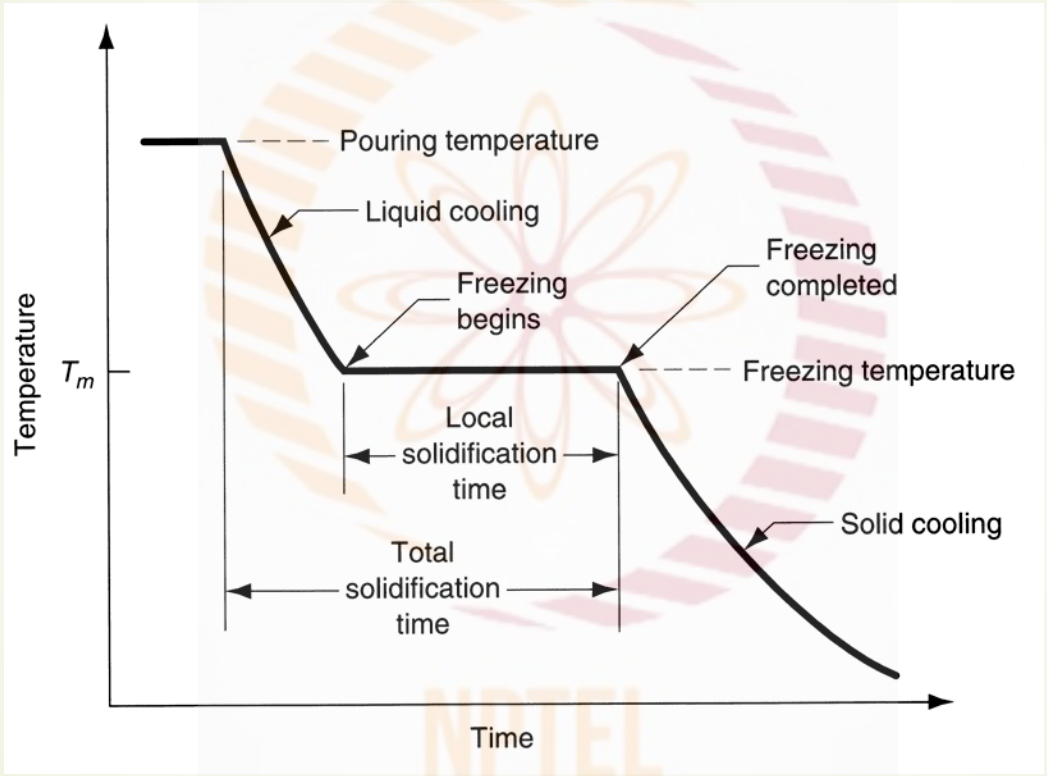
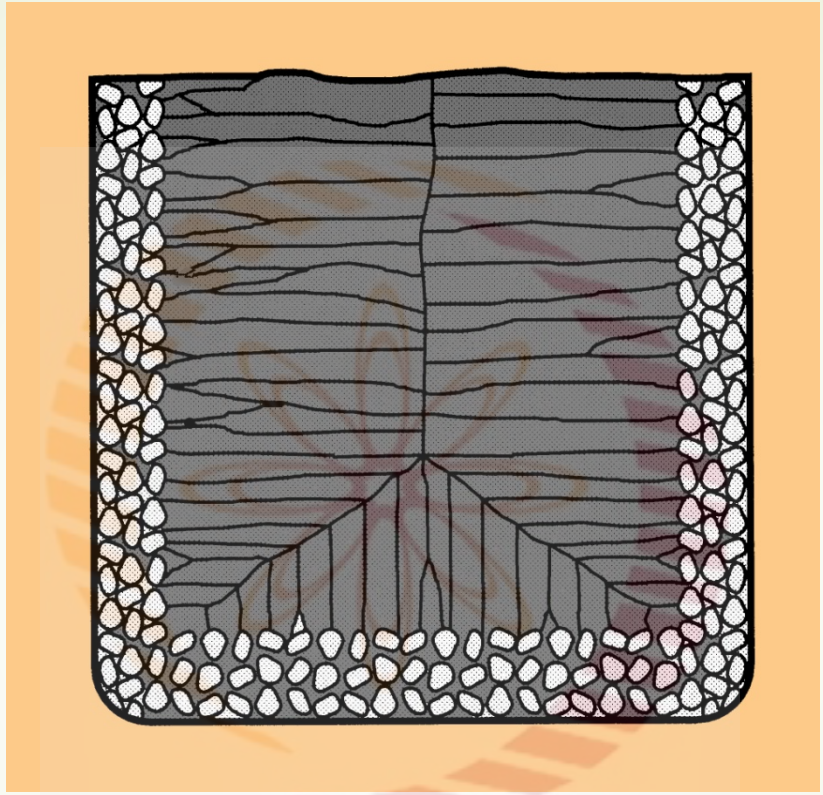
A pure metal solidifies at a constant temperature equal to its freezing point (same as melting point)



Cooling curve for a pure metal during casting

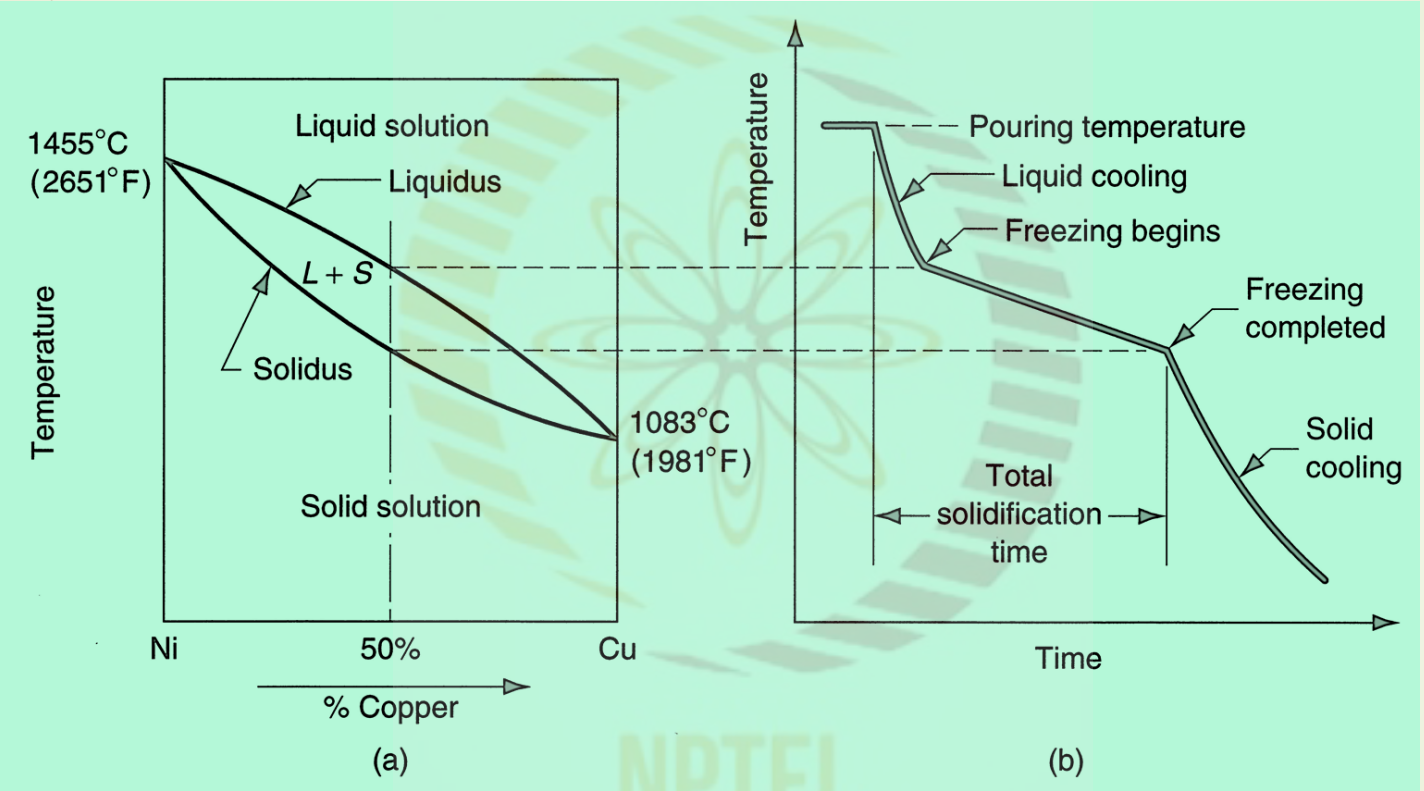
Solidification of Pure Metals

- Due to chilling action of mold wall, a thin skin of solid metal is formed at the interface immediately after pouring
- The metal which forms the initial skin has been rapidly cooled by the extraction of heat through the mold wall. This cooling action causes the grains in the skin to be fine and randomly oriented.
- Skin thickness increases to form a shell around the molten metal as solidification progresses
- Rate of freezing depends on heat transfer into mold, as well as thermal properties of the metal



Characteristic grain structure in a casting of a pure metal, showing randomly oriented grains of small size near the mold wall, and large columnar grains oriented toward the center of the casting

Most alloys freeze over a temperature range rather than at a single temperature



(a) Phase diagram for a copper-nickel alloy system and (b) associated cooling curve for a 50%Ni-50%Cu composition during casting

Solidification of Alloy

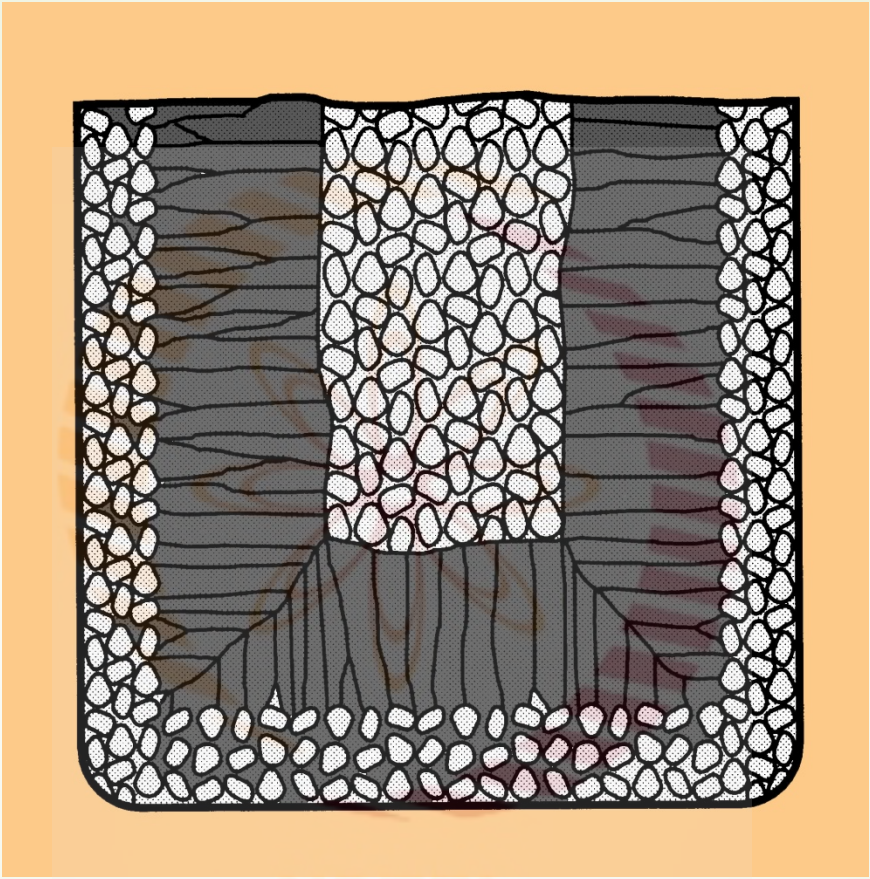
- As temperature drops, freezing begins at the temperature indicated by the liquidus and is completed when the solidus is reached.
- The start of freezing is similar to that of the pure metal. A thin skin is formed at the mold wall due to the large temperature gradient at this surface. Freezing then progresses as before through the formation of dendrites that grow away from the walls.
- However, owing to the temperature spread between the liquidus and solidus, the nature of the dendritic growth is such that an advancing zone is formed in which both liquid and solid metal coexist.

Solidification of Alloy

- The solid portions are the dendrite structures that have formed sufficiently to trap small islands of liquid metal in the matrix. This solid–liquid region has a soft consistency that has motivated its name as the mushy zone.

- Depending on the conditions of freezing, the mushy zone can be relatively narrow, or it can exist throughout most of the casting. The latter condition is promoted by factors such as slow heat transfer out of the hot metal and a wide difference between liquidus and solidus temperatures.

- Gradually, the liquid islands in the dendrite matrix solidify as the temperature of the casting drops to the solidus for the given alloy composition.



Characteristic grain structure in an alloy casting, showing segregation of alloying components in center of casting

Solidification Time

- Solidification takes time
- Total solidification time *TST* = time required for casting to solidify after pouring
- *TST* depends on size and shape of casting by relationship known as *Chvorinov's Rule*