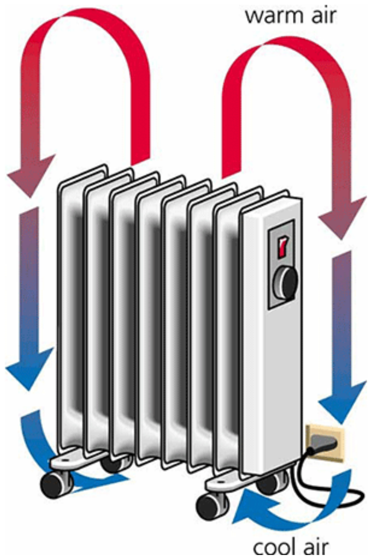
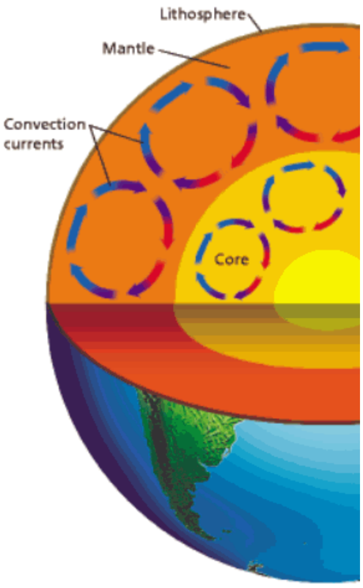
Types of Convection

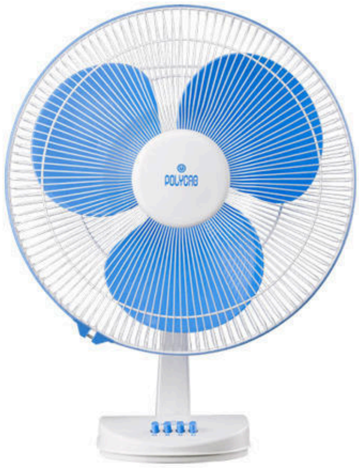
Convection is one of the 3 primary types of heat transfer. When a fluid such as air is heated, its particles then travel away from the source, carrying the thermal energy along with them. This is convection. A radiator is an obvious example of convection, as the radiator heats the air surrounding it near the floor, the air will increase in temperature, expand, and rise to the top of the room. This forces down the cooler air so that it becomes heated, creating a convection current, as shown in the picture.



There are many different types of convection, however we will be focusing on 3 specific types; natural convection, convective boiling and condensation, and forced convection (which can be split into external and internal.)



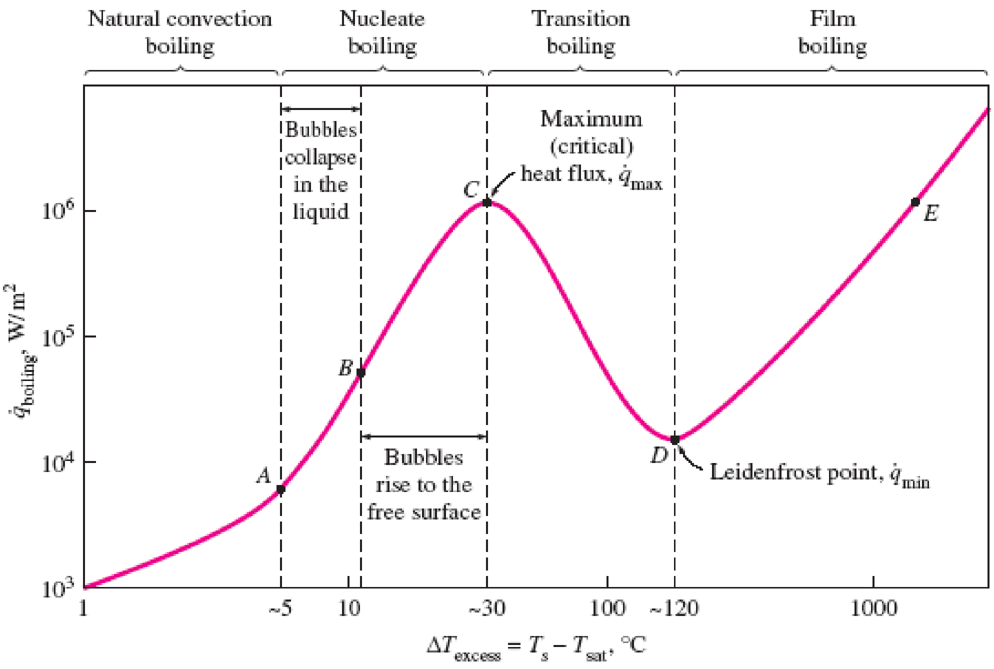
Natural convection is the transport of heat in the which the motion of the fluid is not influenced by any external source like a pump or a fan. The fluid solely moves due to differences in the densities of particles caused by varying temperatures within the fluid. In natural convection, fluid surrounding a heat source receives heat and by thermal expansion becomes less dense and rises. The surrounding, cooler fluid then moves to replace it, before getting heated and the process continues. These actions are what takes place in the Earth's mantle layer, where the heat from the core causes the hotter fluid to rise and convection currents to occur.

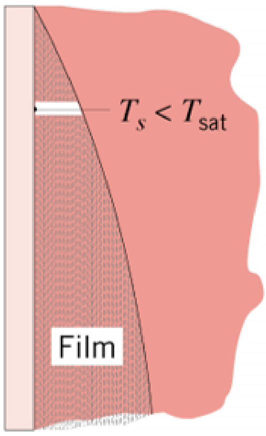


Forced convection is the opposite of natural convection, and is when the transportation of heat is influenced by an external source. It is actually a very useful method of heat transfer as large amounts of heat can be transported at a high efficiency. Creating forced convection is as easy as turning on a fan, it is more common than you would think, mechanisms such as pumps, fans and ovens are found all around us. Without these systems you would find very noticable differences in temperature within buildings as natural convection often causes quite uneven temperature gradients. Forced convection helps create a more uniform and comfortable temperature within buildings.

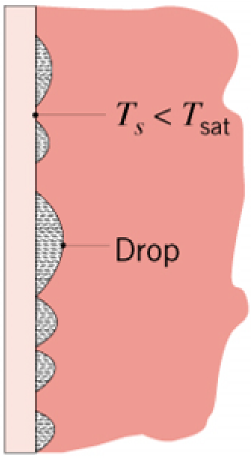
Boiling is associated with transformation of liquid to vapor at a solid/liquid interface due to convection heat transfer from the solid. The agitation of fluid by vapor bubbles causes large heat fluxes and high convection coefficients at lowish temperatures. The motion of the fluid is due to these convection currents and the motion of the bubbles under the influence of buoyancy. Boiling can also be caused by conduction and radiation, this is the case with 'film boiling'.

A boiling curve shows how the conditions of saturated pool boiling are affected by temperature, they are plots of heat flux against the excess temperature of the fluid. Here is what a typical boiling curve looks like:





Condensation occurs when the temperature of a vapour is reduced below its saturation temperature, there are two main types, 'film condensation' and 'dropwise condensation'.
In film condensation, the surface over which the steam condenses is wet-able and as the steam condenses a film of condensate is formed. This process results in low heat transfer rates as this film blocks most of the heat transfer. The level of thickness of the film depends on many factors such as the angle and viscosity of the surface.



Dropwise condensation takes place when the surface over which condensation takes place is non wettable. In this process, droplets are formed when the steam condenses. These vary in size from just a few micrometers to droplets which can be seen with the naked eye. When the droplets are bigger they simply fall under gravity, this type of condensation is what you would associate with surfaces steaming up in your bathroom when you have a shower. In this process there is less thermal resistance due to there being no condensate film, so higher heat transfer rates are achieved. Chemicals are used in industry to ensure that condensation takes place drop wise due to this benefit.

The Nusselt Number (Nu) is the ratio of convective to conductive heat transfer across the boundary. A Nusselt number close to one, with convection and conduction of a similar magnitude is a characteristic of laminar flow. A larger Nusselt number corresponds to more convection, with turbulent flow in the range of 100-1000.

$$\mathrm{Nu}_L = \frac{\text{Convective heat transfer}}{\text{Conductive heat transfer}} = \frac{h}{k/L} = \frac{hL}{k}$$

Reynolds number (Re) gives us similar information to the Nusselt number, it tells us whether the flow is laminar, transient or turbulent. A value of less than 2300 tells us the flow is laminar, and greater than this tells us that the flow is turbulent. If the value is very similar to 2300 the flow will be in the transient stage.

$$Re = \frac{\rho V D}{\mu}$$

$\mu - fluid\ dynamic\ viscosity\ in\ kg/(m.s)$

$\rho - fluid\ density\ in\ kg/m^3$

$V - fluid\ velocity\ in\ m/s$

$D - pipe\ diameter\ in\ m$