# Cooling using steam

Cooling is a major challenge to any vacuum transportation. Virtually every electrical or mechanical device produces heat , which is normally dissipated into the air. But in a vacuum, there is no air cooling, and the heat would just build up. So the electronics, motors, bearings, and passenger cabin all need to be cooled.

### *Alpha's cooling problem*

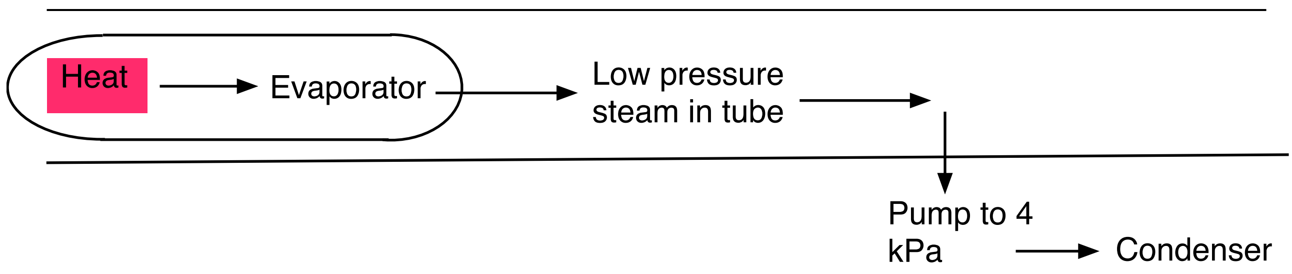
Hyperloop Alpha proposed using water for cooling its motors, compressors etc. The proposal required 290Kg of water over the 35 minute journey. But Alpha proposes storing the steam from the boiled water, which is a serious miscalculation. If we boil this water at 100 C, it will produce 486 cu M of steam, which is an impossible sized tank. Boiling at a lower temperature requires a bigger tank.

Ice could be used for cooling, but the latent heat of fusion of water is much lower. It would take 1,600 kg of ice to cool 250 kW for 35 mins. But that ice would require over 400 Kw to make, pump and transport, more than doubling the overall energy cost.

**Latent heats** for steam and ice
Vaporisation of water 2260 kJ/Kg
Fusion of water (ice) 334 kJ/Kg

### *Steam cooling with ejection into the tube*

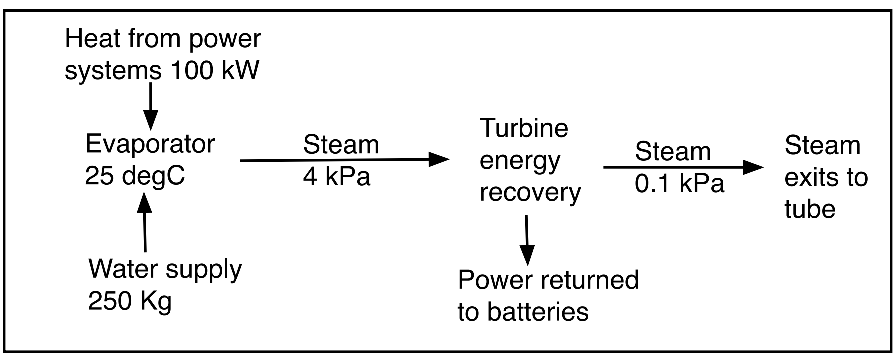
Steam is an excellent heat transfer fluid, which why it has always been used for power generation. The conversion of water to steam is ideal to absorb Hyperloop's waste heat, it would require about 250kg of water. But the steam needs to be disposed of.




Cheetah solution uses cooling water like Alpha, but it ejects the steam into the tube, where it is pumped out to condensers. The pod would have a heat exchanger which boils the cooling water at about 25 C, to cool the air for the passengers, water for the electronics, and oil for the mechanical equipment.

The steam after the evaporators is at 4 kPa, and energy is wasted if it is simply ejected into the tube at 0.1 kPa. This energy could be saved by using it for thrust, or driving a turbine to recover part of the 93 kW required to compress the steam into the condensers.

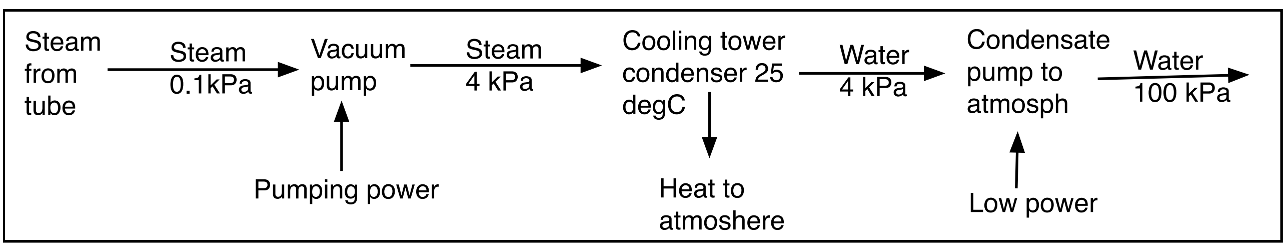
### *Ejecting the cooling steam into the tube*




Heat from the various power system is absorbed by a chilled water system. This is cooled by an evaporator, cooled by water boiling at 25C when the regulated pressure is 4kPa.

The flow of steam is then ejected into the tube, with a small turbine recovering energy as the steam is expanded from 4kPa to 0.1kPa in the tube.

### *Removing the cooling steam from the tube*




This chart shows the method of removing the cooling steam from the tube.
The steam in the tube is at 0.1kPa, and it needs to be pumped up to 4kPa, so it can be condensed in cooling towers at 25C. The condensate is then pumped up to atmospheric pressure for removal.

In theory, the pumping energy from 0.1 to 4 kPa should be recovered by the turbine in the pod, but in reality there are inefficiencies and a power loss. The power cost for cooling will increase the total system energy consumption by about 20%

### *Spot cooling*

Most of the cooling would use a chilled water system. But isolated devices can be spot-cooled just by feeding a small quantity of water, which is evaporated to steam.

The wheels need to be cooled. A small water flow could be passed through the axle, and sprayed onto the inner surface of the wheel. The water would evaporate, and the steam would pass out into the tube.

## Steam increases the speed of sound, reduces drag

There is an substantial advantage to having the tube filled with steam (water vapour) instead of air. This increases the speed of sound by 24%, from 1,245 km/hr to 1,540 km/hr, which is a real benefit for the aerodynamics and shockwave problems.

At 1,200 km/hr, the Mach no. reduces from 0.96 in air, to 0.78 in steam. The graph below shows how much the drag coefficient increases as the Mach no. approaches 1, the 'sound barrier'.