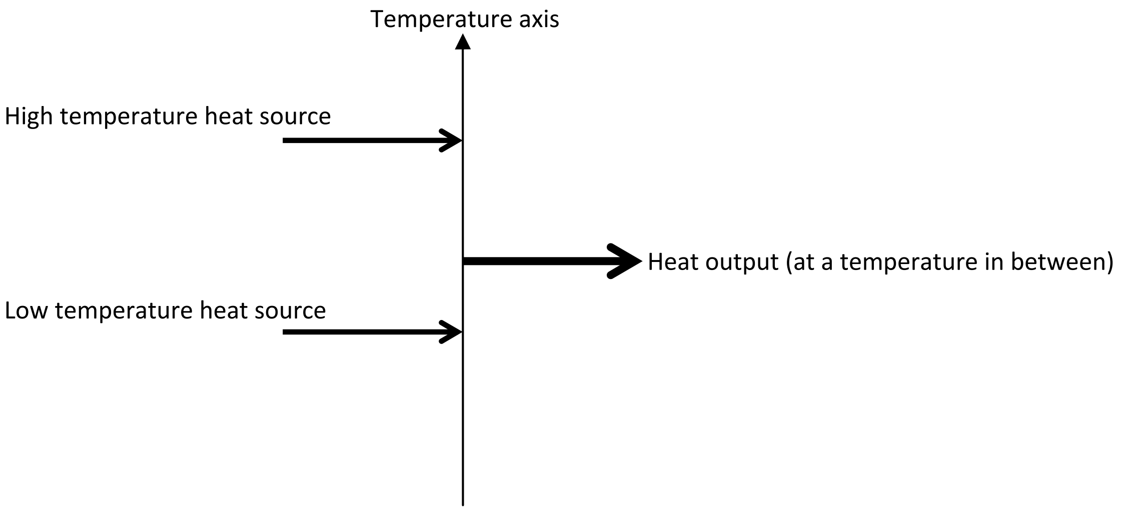
Possible use of absorption cooling

Basically, absorption cooling makes it possible to take heat from two temperature levels (a low temperature heat source and a high temperature heat source) and to deliver the total input of heat at a temperature in between. For making the process thermodynamic possible, the outlet temperature has to be closer to the temperature of the low temperature heat source than the temperature of the high temperature heat source.

Graphically it can look as follows:



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A more full filling description is given in the following, giving a more detailed description of the actual limitations.

1. Since the refrigerant consist of pure water, operating temperatures below 0 °C are not possible. In fact, without special precautions, it is not realistic with chilled water temperatures below 6 °C. This is for giving an acceptable margin between the operating temperature and the antifreeze temperature setting for generating a safety shot down.

2. For limiting the corrosion rate, generator temperatures above 150 °C are normally avoided (the internal temperature of the Lithium bromide from the generator).

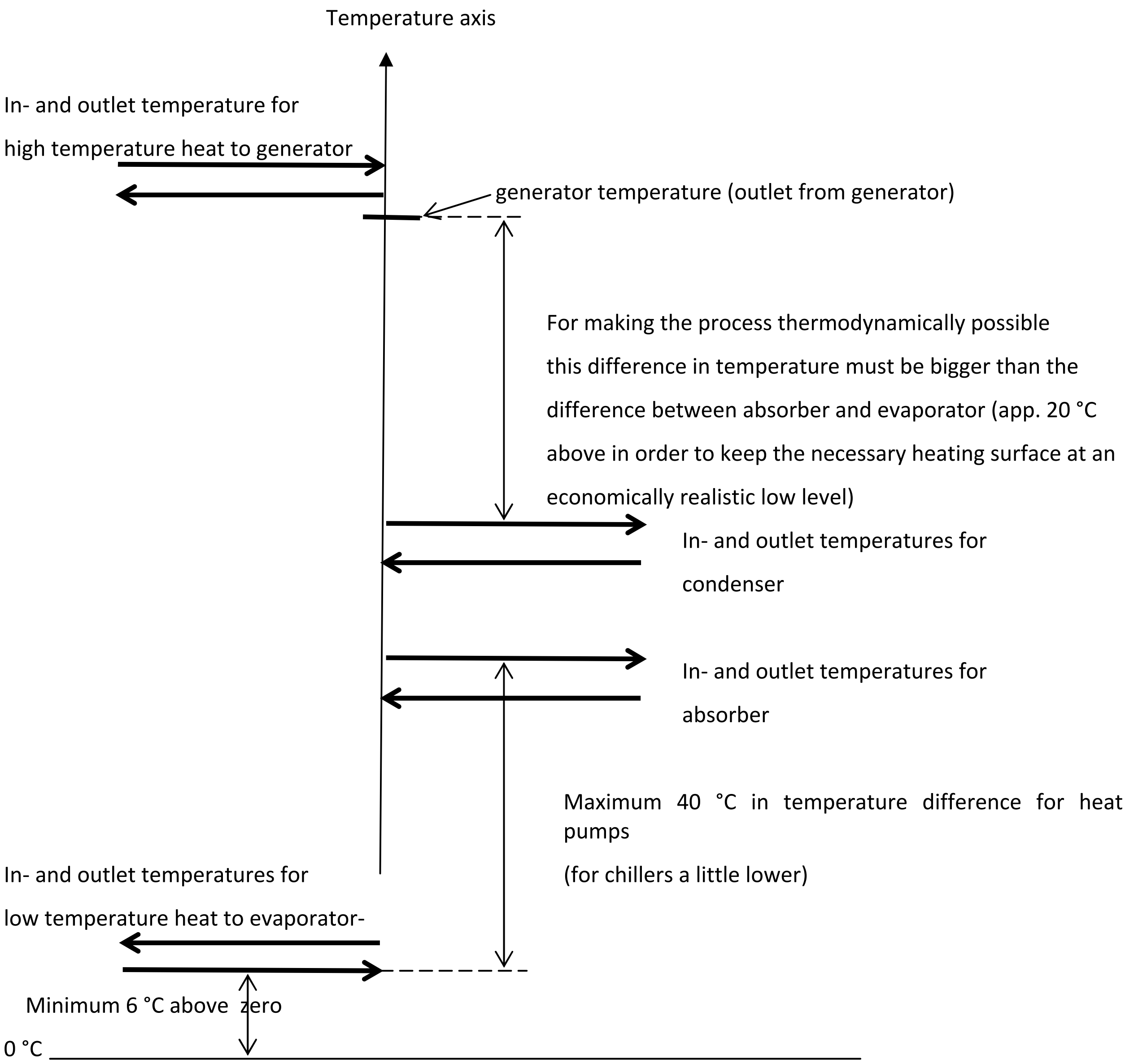
3. Higher difference in temperature between evaporator and absorber requires higher concentration of the Lithium bromide. The maximum allowable Lithium bromide concentration is equivalent to approximately 40 °C of difference in temperature. For achieving the necessary concentration of the Lithium bromide it typically requires a difference in temperature between condenser and generator that is 20 °C above the difference in temperature between evaporator and absorber (outlet temperatures). Increasing the areas of the heating surfaces can compensate a little if the combination of temperatures are insufficient to fulfil the demand described above.

4. Heat output does not come from one, but from two places in the process, and they do not necessarily have the same temperature level. App. 56 % of the heat output is generated in the absorber by absorbing the vapour from the evaporator and app. 44 of the heat output is generated in the condenser by condensing the vapour from the generator. Cooling water for absorber and condenser is normally arranged in serial connection. For chillers (low temperature machines for producing chilled water for cooling purposes) condenser is normally arranged before the absorber. For heat pumps (high temperature machines for producing heat) absorber is always arranged before condenser when arranged in serial connection. However, other connections are also possible.

5. The energy extracted from the low temperature heat source represents 70 – 75 % of the high temperature heat input. Since the heat of vaporisation for water is dominating compared to heat capacity (related to a few degree of variation of the temperature) this figure is almost independent of load and operating temperatures for a given machine.

6. The internal electric power consumption for an absorption machine is mainly used for operating two small circulation pumps. For larger machines (in MW size) the electric power consumption is app. 0,2 % of the chilling power. For the smallest machines (100 kW), the electric power consumption is app. 1 % of the chilling power. Therefore, this consumption is always rather insignificant. More power is necessary for circulation the water through the external connected circuits. However, for heat pumps, this consumption is comparable to alternative ways of producing heat.

At the next page, a more fulfilling sketch can illustrate the given comments.



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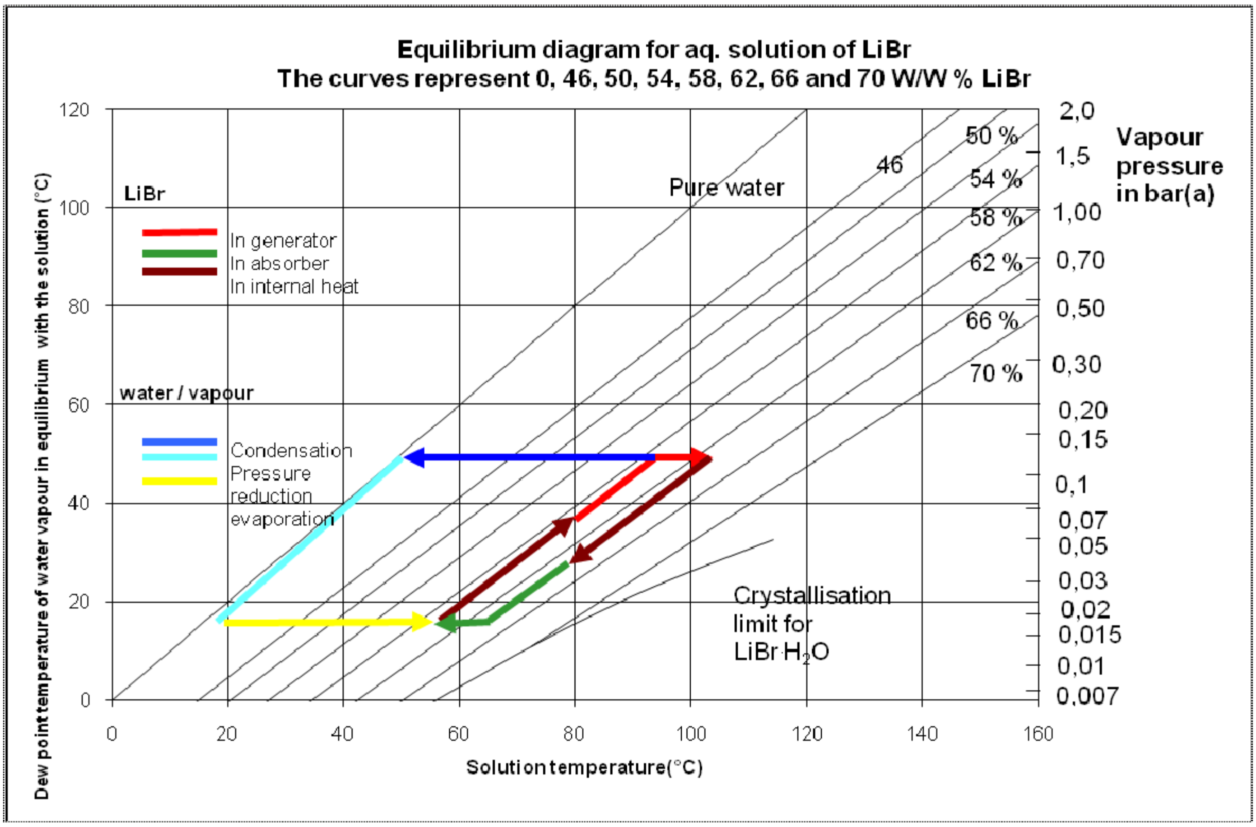
Absorption cooling using water as refrigerant and Lithium bromide as absorbent

How does it work

The main Principe behind this technique is the hygroscopic behavior of Lithium bromide. The vapor pressure for an aqueous solution of Lithium Bromide is much lover than for pure water at the same temperature. The diagram below describes the phenomena.



As an example, pure water at 20 °C has a vapour pressure of 0,0234 bar(a). At the diagram, it can be seen that the vapour pressure is the same for a 58 % aqously solution of Lithium bromide at 57 °C or a 62 % solution at 66 °C. It can be mentioned that the vapor consist of pure water vapor. The salt (Lithium Bromide) does not evaporate at all.

Therefore, the three fluids mentioned above are in pressure equilibrium. However, if the temperature of the pure water was just a little higher (could be 21 °C) the pressure of the pure water would be a little higher than the vapour pressure of the Lithium Bromide giving the following result.

Water would evaporate at 21 °C and would be absorbent to the Lithium Bromide at a higher temperature. Water would take the heat of evaporation at 21 °C and the heat of condensation plus some heat from diluting the salts would be delivered at 57/66 °C. At the same time, the Lithium Bromide absorbs so much vapour that the concentration decreases from 62 % to 58 %. This is precise what happens in the lower shell of an absorption heat pump of chiller.

After absorbing the water vapour, the Lithium Bromide has to be regenerated in order to maintain the vapour absorption process.

In the generator, the Lithium Bromide solution is regenerated by heating to a much higher temperature making the solution boil. The boiling removes the water from the solution again.

The concentrated solution (could be 62 % LiBr) flows back to the absorber through a counter flow heat exchanger and the ring is closed. The water vapour from the generator is condensed in the condenser and flows back to the evaporator through a steam trap (consisting of a simple U-tube at chillers). For heat pumps, the condensate is normally pre-cooled before meeting the lower pressure in the lower shell.

Other chemicals

In addition to the main chemicals (Lithium bromide and water) Octyle alcohol and Lithium molybidate is also added.

The alcohol is a wetting agent, giving a better distribution of the liquid at the external surfaces of the tubes. This gives an increased heat transferring. The added amount of alcohol should just represent about one thousand of the weight of the Lithium bromide.

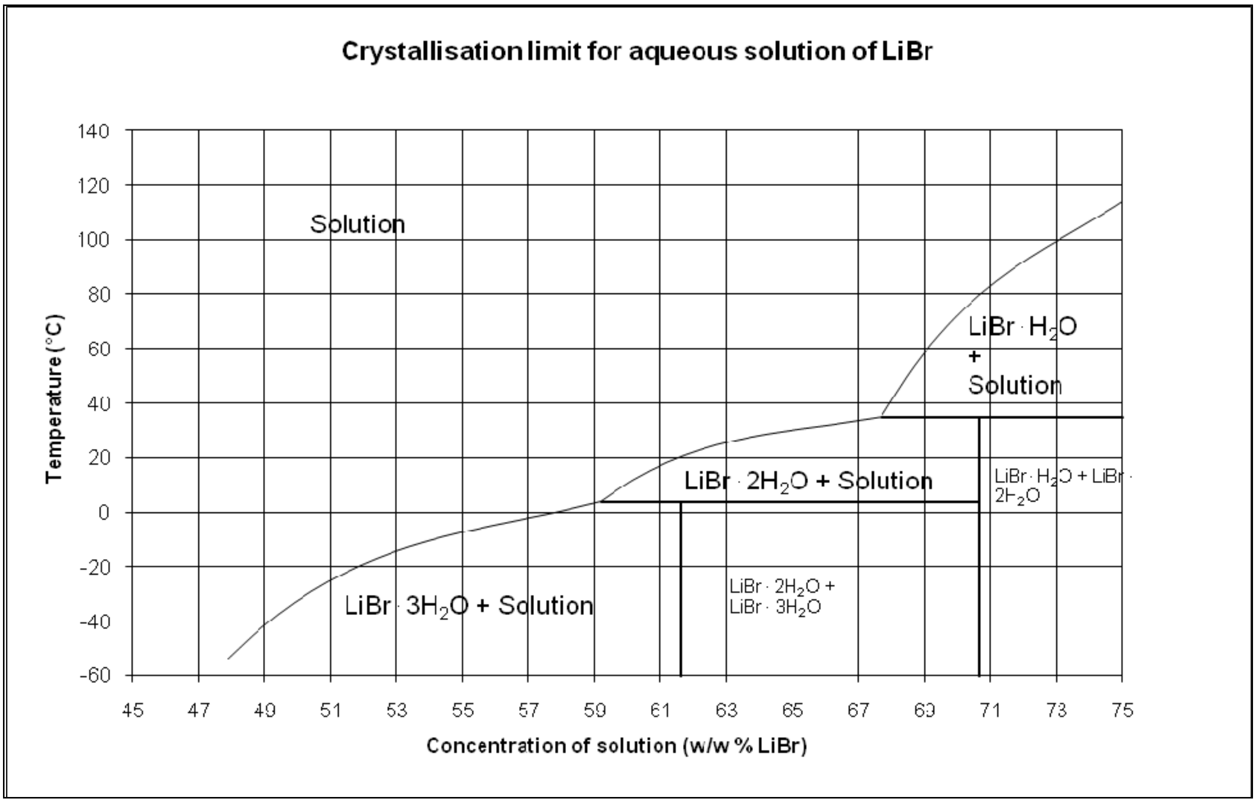
Lithium molybidate is a corrosion inhibitor promoting the formation of an inhibited layer at the internal steel surfaces.

Three things to be avoided

Damage of the evaporator tubes as a result of freezing is traditionally considered as the worst possible risk. However, it is mainly a problem for chillers with operating temperatures just a few degrees above the freezing point of water. Therefore, all machines are equipped with two flow alarms and an antifreeze temperature switch as well as a temperature sensor. Should one of these anti freeze alarm be activated an emergency stop will be executed stopping both internal pumps.

Intrusion of air into the machines should also be avoided. When having internal vapour pressures of a fraction of an atmosphere, even very small amounts of air will give a significant reduction of the thermal capacity for an absorption cooling machine. The air will be accumulated around the absorber tubes, more or less preventing the steam from reaching the absorber tubes. Oxygen from the air will also allow corrosion if it enters the internal of an absorption cooling machine. Therefore, absorption cooling machines are always filled with nitrogen when doing any king of repair involving the internal part.

Finally, if the difference in temperature between generator and condenser gets too high the concentration will also be too high. When cooling a high concentrated lithium bromide solution it can crystallize (become solid). See the crystallization diagram for LiBr at the next page.



However, crystallisation rarely occurs and normally it does not give any damages of the machines.

Maintaining the process

Two things can inhibit the described process.

As mentioned above, air in the machines is one of them. There are two possible sources for air (in fact non condensable gases). Air coming in from the surrounding air is one of them. The other source is Hydrogen formed by the reaction between steel and water forming hydrogen and rust. Non condensable gases can be removed with the vacuum pump. For chillers, this is normally done once a week or less. For heat pumps the need for purging vacuum, is bigger. Electrically heated Palladium cells can also remove hydrogen from the machines with a passive process (normally only small amounts from chillers).

The other possible problem is Lithium bromide in the refrigerant water. By nature, lithium bromide salt does not evaporate and drops from the generator should be prevented from reaching the condenser. However, after long time of operation, microscopic drops can bring some lithium bromide from generator to the condenser. This LiBr salt will be accumulated in the evaporator. Too much Lithium bromide in the refrigerant water will inhibit the cooling. The problem is solved by doing blow-down from evaporator to absorber. The need for blow-down can vary from weekly to monthly.

Checking the oil in the vacuum pump (quality and quantity) should also be done (the need is highly dependent on operating conditions).

Service

The actual service typically consists of taking a sample of the lithium bromide for analyses once a year.

The sample is normally analyzed for :

Inhibitor (Molybidate), alkalinity and perhaps Cupper and Iron if found relevant.

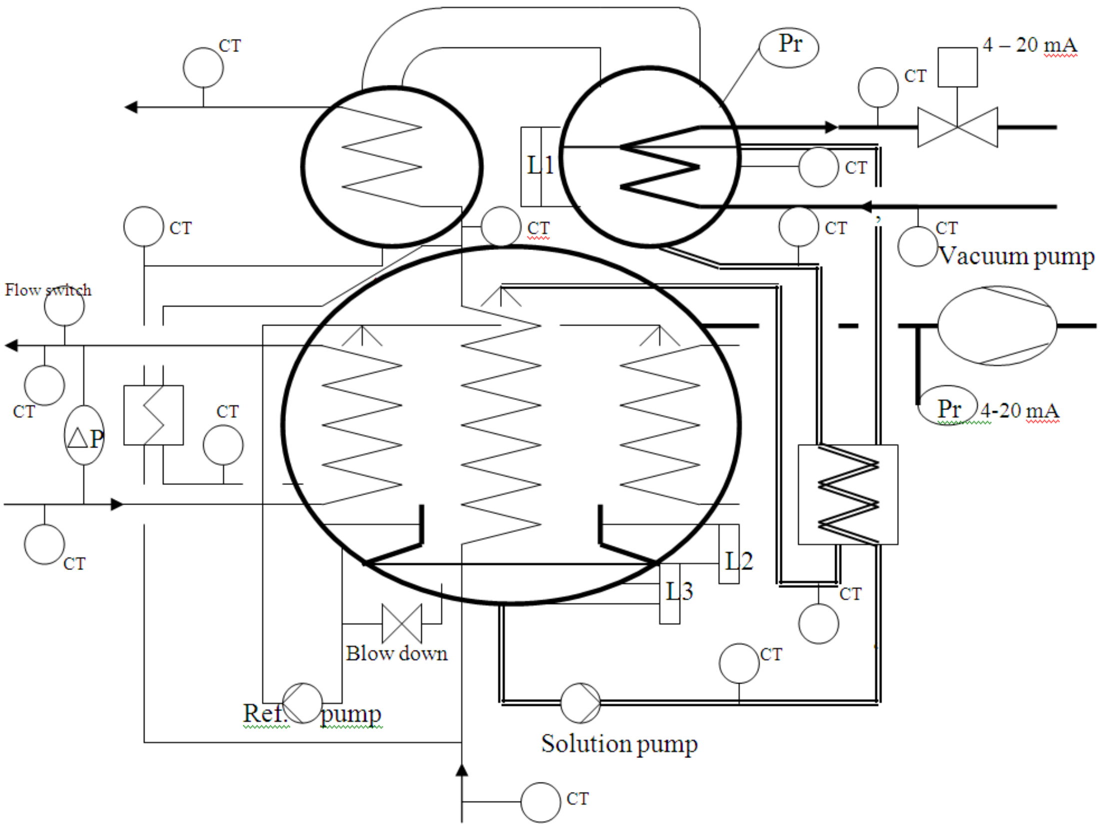
If the alkalinity is too low, LiOH is added. Is it too high HBr can be added.

Is the level of inhibitor insufficient extra should be added (up to 300 ppm).

Need for extra alcohol is determined by smelling.

The TRG-reading is taken for the two pumps. Increased space between pump shaft and bearing (wear) can give vibrations and will an increased TRG reading.

Principe sketch of how a machine can look



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