Recirculating Chiller
Evaluation process for a recirculating chiller

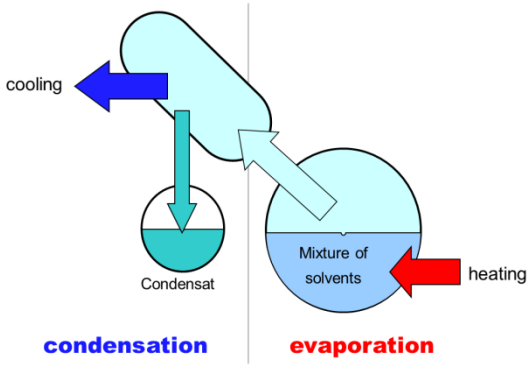
1. Question

What type of a recirculating chiller is recommended as a cooling source for a rotary evaporator, and what are the correct settings?

2. Energy balance of a distillation

The recirculation chiller is needed to support the rotary evaporator with sufficient cooling to condense the vaporized solvent. To ensure the distillation is in balance, the energy for evaporation and condensation of the solvent should be equal.

Figure 1: *energy flow in a rotary evaporator*



3. Required cooling capacity

Every solvent has its own heat of vaporization (also known as heat of evaporation or enthalpy of vaporization). This is the energy required to transform a given quantity of a substance into vapor at a given pressure. In other words, this is the energy that is needed to evaporate a substance.

The maximum distillation rate with a laboratory rotary evaporator is approx. 1.3 liter of water per hour. Now we need to know, what that means in Watt.

Calculation:

$$\left(\frac{\text{heat of vaporization} \times \text{distillation rate}}{3600\ \text{s/h}}\right)$$

The heat of vaporization for water is 2261 J/g (2261 Ws/g).

$$\left(\frac{2261\ \text{W s} \times 1300\ \text{g x h}}{\text{g} \times \text{h x}\ 3600\ \text{s}}\right) = 820\ \text{W}$$

This means 820 W are needed to evaporate 1.3 kg of water.

According to above explained energy balance, it also requires 820 W cooling capacity to condensate the evaporated solvent.

To achieve the maximum distillation rate, the rotary evaporator has to be operated at high bath temperature (above 80 °C).

Only less than 10% of all users of a rotary evaporator are running their system at maximum distillation rate. Typical bath temperature is about 50 °C.

At different bath temperatures the distillation rate is also different.

Example:

Bath temperature	Boiling point	Distillation rate of water	Corresponding power
80 °C	30 °C	1.3 L/h	820 W
60 °C	30 °C	1.0 L/h	650 W
50 °C	30 °C	0.8 L/h	500 W
40 °C	30 °C	0.6 L/h	350 W

In the table above it is evident that at a typical bath temperature of 50 °C and a boiling point of 30 °C, 500 W is used for the evaporating of 0.8 liter water/hour. According to the energy balance, also 500 W cooling capacity is sufficient for this distillation.

4. Suggested cooling temperature

Often customers set the chiller to the lowest possible temperature, but is this the right approach?

For the best evaporation performance we need a significant temperature difference between the heating bath and the boiling point. On the other hand the boiling point should be above ambient temperature, otherwise the collected distillate will start boiling in the receiving flask and the vapor may get loose through the vacuum pump.

Consider this, the recommended boiling point should be about 30 °C in most cases.

For an efficient condensation, a temperature difference of 15 °C between vapor and cooling is needed. This means a sufficient condensation can already be guaranteed with +15 °C cooling temperature.

5. Higher efficiency at -10 °C?

Recirculating chillers are designed for a certain cooling capacity at a defined temperature. This is possible by choosing different refrigerants and compressors. Also the amount of refrigerant has an influence. Nevertheless, all the recirculation chillers have one thing in common.

⇨ The cooling capacity is related to the cooling temperature.

Example (Recirculating Chiller F-305):

Cooling temperature	Cooling capacity
20 °C	620 W
15 °C	550 W
10 °C	440 W
0 °C	250 W
-10 °C	80 W

As a consequence of this fact, a lower set temperature has no advantage, as it would anyway rise up to the level, where the cooling capacity will be sufficient for the condensation.

6. Conclusion

- Most lab size rotary evaporators are not operated at their performance limit. Typically they run at bath temperature of 50 °C which results in about 60% of the maximum distillation rate.
- A boiling point (equal to vapor temperature) should be set to about 30 °C to avoid boiling of the already collected solvent in the receiving flask.
- With a vapor temperature of 30 °C, a cooling temperature of 15 °C is sufficient for the condensation of the generated vapor.
- At this condition, an evaporation rate of 0.8L water/h (or equivalent for other solvents) can be achieved.
- To condensate 0,8L/h of water, a cooling capacity of about 500 W is needed. This requirement can be achieved with the Recirculating Chiller F-305 at a temperature of 15 °C.
- Low cooling temperatures are usually not efficient, as at low temperature the chillers will not have the needed cooling capacity.

Figure 2: *System with Rotavapor® R-300 and Recirculating Chiller F-305*

Positive side effects of 15 °C cooling temperature are:

- Water as cooling media is sufficient
- Less condensation of humidity on the cooling hoses
- No ice forming on connections and hoses