Accelerating the Path to Discovery™

Improving Rotary Evaporator Efficiency & Sustainability

As chemists seek to reduce their experimentation costs while operating more sustainably, rotary evaporation has come under a spotlight. Processes involving significant changes in temperature, especially when they involve large quantities of liquids or changes in state, are particularly energy intensive. Unfortunately, rotary evaporation most often checks all of those boxes, especially when recirculating chillers are involved.

Recirculating chillers have allowed scientists to avoid the supply constraints of needing a reliable source of dry ice while conserving water. On the downside, they are large, heavy, noisy, require substantial pull-down time before use, and usually consume more electricity than the remainder of the rotary evaporator setup combined, including the vacuum pump. Any effort to make rotary evaporation a more efficient process should start with that most energy intensive component. Why are chillers so inefficient?

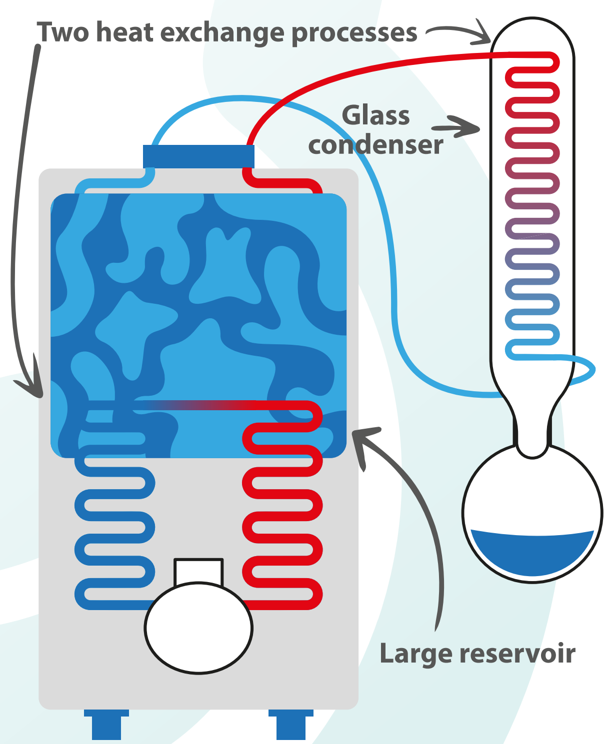
Using a recirculating chiller with a rotary evaporator involves using a compressor to remove heat from a relatively large volume of a secondary coolant liquid (usually a water / glycol mixture), which is then pumped through a glass condenser to remove heat from the vapor.

Three inefficiencies can be readily identified:

1 There are too many cooling steps. Each heat removal step is not perfectly efficient. There is some loss involved. So having two such steps is less efficient than if there could be one.

2 The large volume of liquid in a chiller. The volume of a condenser in a benchtop rotary evaporator is generally under half a liter, but the reservoir in a bench-scale recirculating chiller is often 4 liters or more. That leads to the long pull-down times. The longer the chiller is running and cooling without an experiment being run, the more inefficiency is introduced.

3 Glass is not the best thermal conductor. Metal would be much better.



The Hydrogen by Ecodyst set out to solve all these inefficiencies by pumping refrigerant from the compressor directly through metal coils inside the condenser. Scientists won't just accept anything without quantifying it, however, so The Brennan Research Group at the University of Oxford set out to find out just how much more efficient - in terms of both electricity and time - the Ecodyst Hydrogen Technology is compared to a traditional rotary evaporator setup with a recirculating chiller filled with an ethylene glycol solution. This comparative study measured the energy consumption of two systems when carrying the distillation of 100 milliliters of cyclohexane. The experiments were conducted separately and the vacuum controllers were set to the same settings.

	Unit Set Up		
Equipment Set Points	**Rotovap with Chiller**	**Ecodyst Hydrogen**	**Ecodyst Hydrogen**
Chiller Set Temperature	**-10C**	**-10C**	**-34C**
Rotovap RPM	180	180	180
Vacuum Set Point	120mbar	120mbar	120mbar
Water Bath Set Temperature	40C	40C	40C
Water Bath Fill Volume	3.5L	3.5L	3.5L
Preparation Data			
Chiller Energy/Ecodyst Hydrogen Pull Down Time	70 minutes	1 minute	5 minutes
Chiller Energy Pull Down Energy (kWh)	0.225		
Water Bath Warm Up Time	5 minutes	7 minutes	7 minutes
Water Bath Warm Up Energy (kWh)	0.063		
Ecodyst Chiller Pull Down & Bath Warm Up Energy (kWh)		0.107	0.132
Energy Used to Reach Set Points (kWh)	0.288	0.107	0.132
Distillation Data			
Duration	20 minutes	30 minutes	20 minutes
Chiller Energy (kWh)	0.101		
Water Bath (kWh)	0.027		
Rotovap (kWh)	0.012		
Ecodyst Hydrogen Energy (kWh)		0.067	0.083
Total Energy Consumptions			
Distillation Total Energy/kWh/Hr	0.14	0.067	0.083
Preparation + Distillation Energy (kWh)	0.428	0.174	0.215
Preparation Time + Distillation Time	90 minutes	37 minutes	27 minutes

Table 1 - Experimental conditions and data recorded during the comparative study for the preparation and distillation steps.

As per Table 1, this comparison shows that the Ecodyst Hydrogen's preparation is 10 times faster. It only took 7 minutes for all the components to be ready while the chiller of the traditional rotary evaporator required 70 minutes. Moreover, the distillation was almost twice as energetically efficient when using the Hydrogen system which consumed 0.067 kWh, as compared to the rotovap with a chiller that consumed 0.140 kWh.

	Unit Set Up		
Equipment Set Points	**Chiller**	**Ecodyst Hydrogen**	**Ecodyst Hydrogen**
Chiller Set Temperature	**-10C**	**-10C**	**-34C**
Pull Down Time	**70 minutes**	**1 minute**	**5 minutes**
Pull Down Energy (kWh)	**0.225**	**0.025**	**0.043**
Chiller Energy/Ecodyst Hydrogen Energy (kWh)	0.303	0.012	0.109
Pull Down + 8 Hours Usage/Day (kWh)	2.649	0.121	0.915
Yearly Cost (240 days use/year)	€ 120.79	€ 5.52	€ 41.72
TCO2e/Yr	0.1481	0.0068	0.0512

Table 2 Experimental conditions and data recorded during the comparative study for the chillers.

As per table 2, we notice that the Hydrogen consumed 0.012 kWh/hr to reach the -10ºC setpoint in only one minute, while the traditional chiller consumed 0.303 kWh/hr over 70 minutes to reach that same temperature. The Hydrogen was able to achieve -34ºC in 5 minutes while having consumed 0.109 kWh/hr.

The Ecodyst Hydrogen's chiller pumps the refrigerant directly into a metalcondenser, which entails many advantages. First by eliminating the need for a separate recirculating chiller, the footprint of the equipment is drastically reduced. Second, since the metal condenser has a very high thermal conductivity, the use of Hydrogen accelerates cooling times and allows reaching minimum temperatures of 40ºC in 5 mins. Reducing the pull-down time to a maximum 5 minutes (compared to 70 minutes to reach -10ºC with an ethylene glycol recirculating chiller) directly reduces the run time of the machine. In addition, when very low temperatures are attained the chiller can be turned off while the evaporation is ongoing thus cutting the total energy consumption of the operation by 50%. Furthermore, since there is no longer a need to use a secondary coolant liquid, there is additional cost reduction and environmental savings.

Researchers can use this technology to tackle the most tedious aspect of solvent separation and accelerate their extraction protocols, saving over an hour of pull-down time per experiment. The overall carbon footprint of their experiments will also be cut tremendously due to the reduced electrical consumption and eliminating the use and replacement of coolant fluid.