WHITE PAPER No. 53

# Air Cooling or Water Cooling?

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## Executive Summary

ULT freezers offer a save storage location for your valuable samples. While generating -80 °C at one part of the instrument, the freezer also creates heat. This heat needs to be removed from the ULT freezer. The heat needs to be neutralized by removal from the freezer via air or water cooling. This paper describes the differences between the two cooling types as well as indicating the aspects within the building set-up required for water cooling.

### How can you create cold?

Reliable -80 °C are generated by passive support (i.e. insulation or gaskets) as well as by active cooling via the compressors. The compressors are literally the core of every freezer.

The compressor creates cold temperature indirectly: The cooling liquid (gas) is compressed within the compressor, the compressed gas becomes hot. You might know this process when you use a bicycle tire inflator and block the exit valve with your finger while pumping.

The gas leaves the compressor while being pressurized and heated. The compressed gas reaches the condenser where the gas finally liquefies. Based on the liquefaction, the heat is removed from the cooling gas/liquid.
In general, there are two ways to remove the heat from the condenser.

### Further process of cooling within the ULT freezer

The temperature of the liquid is still high. By passing a so-called expansion valve, the pressure of the liquid is drastically reduced within a very short timeframe. By this flash-like evaporation from liquid to gas phase, cold is created.

This cold within the cooling pipe is transferred to the cooling loops which enclose the freezer chamber. Locally, the cold is passed to the stainless-steel interior walls of the inner freezer chamber. The cooling loops are even visible at the beginning of the cooling process when you cool down the freezer.

### Air cooling

The classic air cooling of ULT freezers is performed by a fan within the compressor compartment (Fig.1). The fan actively absorbs cooler air from the environment and blows it towards the condenser. Hereby, the heat is blown out of the compressor compartment into the lab environment. The principle is simple and reliable. Unfavorable, the air around the ULT freezer is warming up. Especially when several freezers are located in the same room, the room temperature in this room substantially rises.

The temperature rise must be controlled by passive air ventilation (open window) or by active air cooling (e.g. HVAC). Otherwise, the temperature will reach a critical point where the cooling system of the ULT freezers may break down due to over-heating. As a final result, the tens of thousands of high-value samples will defrost and be lost.

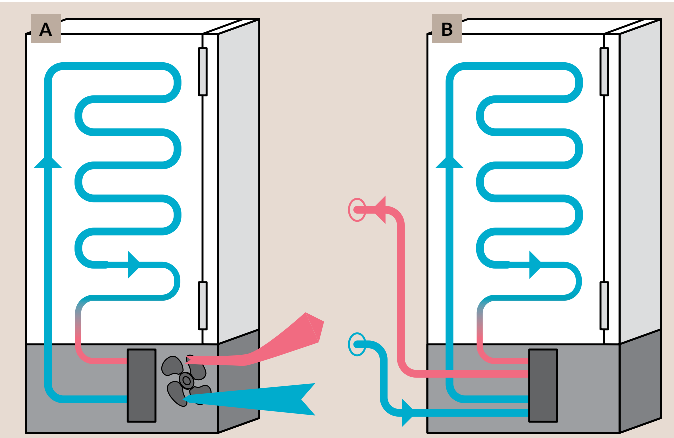


**Fig. 1:** Diagrams of an air-cooled ULT freezer system (A) and a water-cooled ULT freezer system (B)

## Water cooling

For some years now, an alternative method for the freezer cooling is getting more and more attention: water cooling. For this special type of cooling, some adaptions at the freezer are mandatory (Fig.2):

The ULT freezer has an inlet water port and an outlet water port. There is an internal pipe connecting the inlet water port with the condenser and back to the outlet water port. The condenser is equipped with a heat exchanger. A constant flow of cool water at this heat exchanger takes the heat away. In contrast to air cooling, the water-cooled freezer has a lower heat output towards the lab environment.

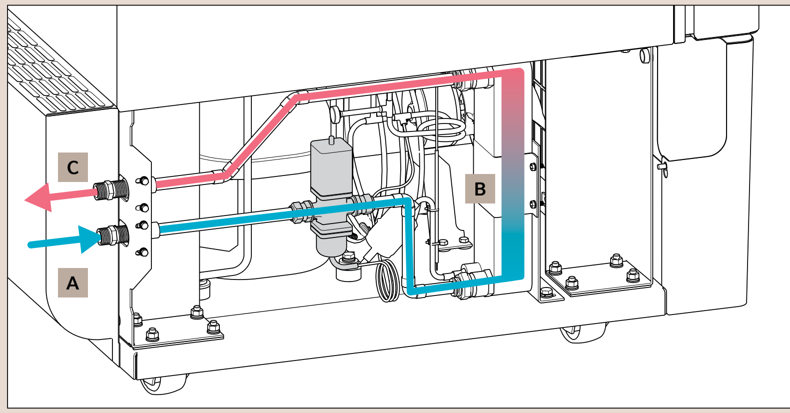


**Fig. 2:** Cooled water enters the freezer through inlet port (A), passes through the condenser (B), absorbs the heat from the freezer, and then exits through outlet port (C) as heated water, carrying the heat away from the freezer

The first water-cooled freezers were using flow water without recirculation (Fig. 3). As the cooling requires approximately 250 m$^3$ of fresh water per year per freezer, the non-circulating system is not recommended due to the high costs for water as well as the negative sustainability factor.

More and more new buildings are designed with cooling water circulation systems (Fig.4). The warmed-up cooling water from the ULT freezer is directed to a heat exchanger which can be part of the central building heating system. This heat exchanger extracts the heat from the freezer cooling water to support the building heating system. When leaving the heat exchanger, the freezer cooling water is cooled down to be re-used at the ULT freezer.

This circulation process saves resources as well as money by supporting the local building heating system. When a new building is designed from scratch including cooling water circulation systems, the air condition systems (HVAC) in those rooms where ULT freezers are planned to be located, can have a reduced dimension.

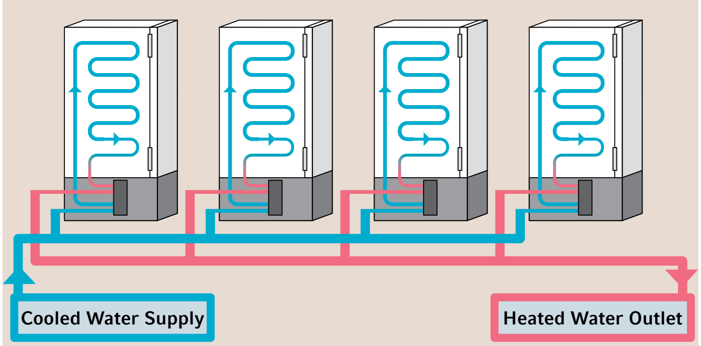


**Fig. 3:** A series of water-cooled freezers with no recirculation; new, cooled water enters the freezers, absorbs the heat in the condensers, and is heated water is discarded from the systems as waste

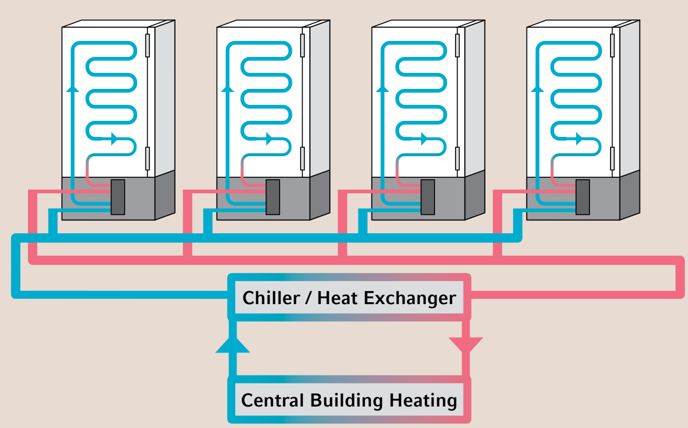


**Fig. 4:** In a circulated system, cooled water enters the freezers, absorbs the heat in the condensers, and then is channeled through a chiller/heat exchanger to be cooled and used again within the system; the heated water that is dispensed by the freezers can also be routed to the building HVAC system to support building heating

### Technical conditions

The cooling water temperature should be between 7 °C and 25 °C.  The water flow rate should be 29 L/ h. The needed water flow rate (L/h) strongly depends on the water temperature as well as on the freezer temperature (Fig. 5). The higher the water inlet temperature, the more water (i.e. higher flow rate) is needed per time. An ULT temperature of -85 °C needs more cooling water per time compared to a freezer temperature of -70 °C.

The cooling water needs to be free of particles as these might clog the valves and the temperature sensors. A water filter can be used. This is to be installed upstream the water inlet port and should have a mesh width of 0.25 mm (60 mesh).

The water pressure should be between 100 kPa and 1,000 kPa. The difference between the water inlet port and the water outlet port is 50 Pa.

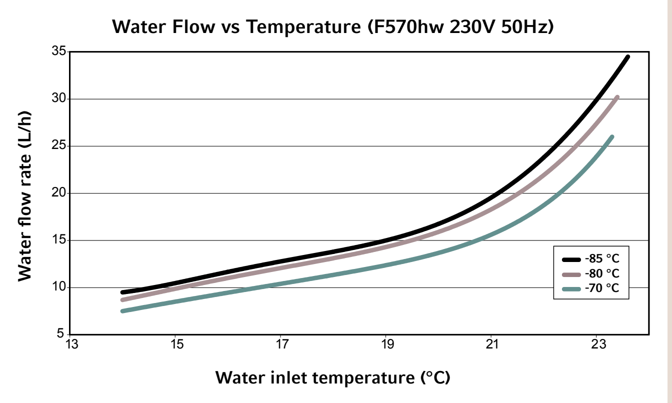


**Fig. 5:** This graph shows the increasing water flow rate (L/h) required for optimal cooling as it relates to increased water inlet temperature and the desired temperature within the freezer; all three variables must be considered when installing a water-cooled ULT freezer system

### Energy saving

The power consumption of the saved fan within the air-cooled ULT freezer is neglectable. The power consumption to cool down the ULT freezer is similar for air cooling as well as water cooling. The most interesting part for energy savings and sustainability is the handling of the extracted heat of the ULT freezers. The less heat you have to neutralize within the room where the ULT freezers are located, the smaller the HVAC needs to be or the less the existing HVAC needs to run.

The absolute energy saving of water-cooled ULT freezers is challenging to estimate as it is a multi-factor calculation. The volume class of the freezer and the related power consumption defines the heat extraction. That is the amount of heat that must be removed or neutralized. The proportion of the heat which can be removed by water cooling depends on several aspects: the room temperature, the cooling water inlet temperature, the flow rate of the cooling water, the length of the exhaust cooling water pipe from the freezer to the wall (the longer the pipe, the more heat will release from the water back to the room), the material of the pipes (e.g. metal pipes will release heat from the water back to the room), the type of wall (exterior walls are colder than interior walls), etc.

Calculation of HVAC systems and their interaction with ULT freezers need to be handled by experts on air-conditioning. They can also provide you indications about energy savings when using water cooling.

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