Getting the Most from Your Ultra- Low Temperature Freezers

How to extend the life of -80s, reduce costs, and lower risk of failure through smart purchasing and regular maintenance.

Ultra-low temperature freezers (ULTs), often called -80s, are relied upon for long-term sample storage in most life and medical science labs. With high purchase, operating, and repair costs, ULTs present a considerable investment. Their expense combined with the often-irreplaceable samples stored in them make ULTs a common stress-point in the lab. Any freezer failure results in an urgent scramble, while the dreaded off-hour failure can be a catastrophe.

ULTs are notorious for their high energy consumption—second only to fume hoods amongst general lab equipment[1]—which makes them a popular target for improving efficiency and sustainability in science.

Fortunately, the right equipment and proper maintenance can mitigate the risk of failure and improve efficiency. Relatively small changes can have a large impact on longevity, operating costs, and "lab greening" efforts. Purchasing energy-efficient units along with implementing best practices can provide lab managers with both peace of mind and savings.

What makes a ULT freezer energy efficient?

Energy efficiency in ULTs ultimately comes down to the compressor duty cycles—the percentage of time the compressor is running—and the associated energy pull. Under typical field operation, duty cycles are driven by cooling demands and vary between 31 percent and 88 percent depending on the instrument, temperature set point, and use.[1] Anything that contributes to leakiness in the chamber or restricts air flow and heat exchange, particularly around the condenser fins, adds additional strain. The goal is to reduce the number of cycles, which also lengthens the lifespan of the unit.

A suite of technological improvements over the last decade have increased efficiency across all new ULTs, but the largest improvements are seen in energy-efficient models. Specifically, optimizations for fan, compressor, condenser, refrigerants, insulation, and storage capacity (as it affects the number of units required) have all contributed to this trend. The best energy scores are associated with vacuum insulation and natural refrigerants with high heat capacity like R290 (propane)—R290 alone has been reported to increase efficiency by 20 percent.[1] Overall, the average energy consumption of a 21-29 cubic foot energy-efficient ULT freezer is 9.7 kWh/day, saving approximately 7 kWh/day compared to a standard similarly-sized ULT freezer averaging 16.7 kWh/day.[1]

Reduce energy consumption and prolong instrument life with best practices

Regular maintenance is critical to avoid unnecessary strain to the compressor and is likely to greatly extend the life of the freezer. Tasks like cleaning the filter and condenser, wiping seals and de-icing valves, and defrosting, along with replacing or repairing damaged components, will reduce the compressor's workload and help to ensure a long life. As with any lab equipment, training is key—anyone performing maintenance should be adequately trained and familiar with the manufacturer's guidelines. A typical maintenance schedule is provided here as a resource, though users should always consult the maintenance and calibration manuals for specific activities.

Labs can reduce energy consumption considerably by changing usage practices like adjusting the set point and organizing samples. Changing the temperature set point from -80°C to -70°C reduces duty cycles by 56 percent on average (ranging from 32 to 87 percent), enough to bring even standard ULTs set to -70°C in line with energy-efficient units set to -80°C.[1] Recent data suggest that most materials currently stored at -80°C can be stored at -70°C with no deleterious effects, though researchers and lab managers should independently confirm this for their samples. In field tests, recovery time, stability, and uniformity were not impacted by the change in temp.[1,2]

Improving sample organization by instituting a mapping system and culling old or irrelevant samples can equate to surprising energy savings. Better organization can reduce the number and duration of door openings, which directly impacts duty cycles. Repeated door openings within a short period of time causes a spike in the temperature and energy pull.[1] Even modest use pulls 10 percent more energy than during off-hours.

The amount stored in each freezer also makes a difference. Full freezers minimize air displacement when doors are opened, but introducing space between racks to allow air circulation can boost temperature uniformity. Removing one rack per shelf slightly improved average temperature and uniformity, based on reduced standard deviation.[2]

The many benefits of improving ULT energy efficiency

Perhaps the greatest benefit of improving efficiency is the peace of mind accompanying greater sample protection. Reducing strain on the compressor extends the life of the freezer, which in turn reduces the risk of failure. In the event of a power failure, the same features that improve energy efficiency will slow down the warm-up time. Energy efficient models typically take approximately nine hours to warm from -80°C to -50°C, or four to five hours to warm from -80°C to -60°C. The difference between -80°C and -70°C was measured as 1.5 to 2.8 hours.[2]

The reduced energy consumption strategies discussed above come with measurable cost savings. Reducing set temperature to -70°C saves on average 37 percent (ranging from 23 to 50 percent by model).[1] Other best practices like defrosting, cleaning, and removing old samples can reduce energy consumption by up to 30 percent—high profile examples include six CDC labs

Maintenance Chart

Monthly Maintenance

- Visually inspect the condenser air filter for dust, soiling, or damage.
  Wash with water only or mild detergent and dry fully before reassembling. Replace the filter if damaged or too dirty to clean effectively.

- Visually inspect the outer door gaskets for ice buildup.
  Remove frost by wiping with a clean, dry, absorbent cloth, or defrost if hard with ice.

- Visually inspect the inner compartment doors for icing.
  Remove frost by wiping with cloth or ice by scraping with an ice scraper.

- Visually inspect the inner chamber for excessive frost.
  De-ice by scraping or defrost the chamber as needed.

- Visually check the pressure equalization port valve for ice buildup.
  Clear ice as needed.

Bi-Annual Maintenance

- Visually inspect the condenser (or more frequently if the site is dusty).
  Use a vacuum cleaner, or compressed air if necessary, to remove dust from the condenser fins.

- Carry out a test run of any CO2 or LN2 emergency cooling systems.

Annual Maintenance

- Defrost and clean the entire device as required, following cleaning and decontamination protocols provided by the manufacturer.
  Use detergents that are non-corrosive and suited to the materials/interfaces.

- Check housing and inner chamber for any mechanical damage or corrosion.
  Replace any damaged sheet metal components.

- Check outer door for mechanical damage or corrosion.
  Replace door if needed.

- Check outer door for alignment and tight fit, and hinges for smooth, controlled movement.
  Clean hinges and align door if needed.

- Check door gaskets for wear, alignment, and damage.
  Replace door gaskets as needed.

- Check smoothness and function of door lock.
  Clean lock and handle; replace lock if needed.

- Check the housing for the door lock and controller for tight fit or damage.
  Tighten housing screws or, in case of damage, replace the housing.

- Check the functions of the controller buttons.
  Replace housing part as needed.

- Check temperature control calibration.
  Adjusted when necessary.

- Check backup batteries for alarms.
  Replace as needed.

that report over 350,000 kWh/yr in savings combined and the National Institute of Health that reports 25,000 kWh/yr saved for each freezer.[3]

Reducing the duty cycles will perforce decrease heat output, which means less strain on the HVAC systems. A combination of energy-efficient technology and behavior demonstrated an average savings on HVAC energy consumption of 10 percent, varying from 6 to 13 percent based on location, such as in an open lab, a hallway, or a "freezer farm".[1]

A collective adoption of energy efficient ULTs could have a marked environmental impact. The Center for Energy Efficient Laboratories (CEEL) calculated the impact of replacing ULTs at the end of their lifespan with energy efficient units.[1] They estimate savings of 41 million kWh in one year in California—plus 7.6 million kWh peryear in HVAC savings—and 171 million kWh in one year nationally, with savings compounding every year. They expect changing the set point to -70°C for all freezers in California would save another 135 million kWh/year.

Freezer features that improve all-around efficiency

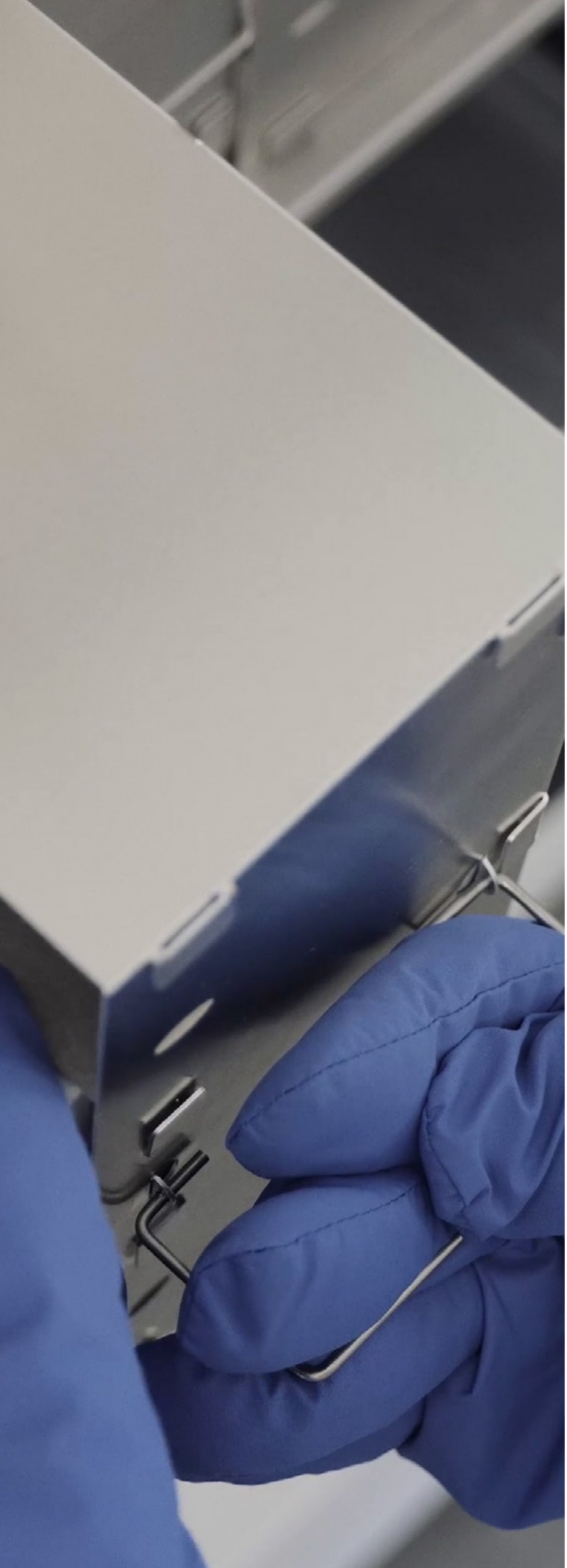
Liebherr's range of ULT freezers surpass the Energy Star baseline performance, offering greater efficiency and peace of mind. Liebherr uses a well-designed compressor cascade cooling system that boosts performance, with natural refrigerants (R290 and R170) for both greater efficiency and reduced environmental impact. Combined vacuum insulation technology and CFC-free PU foaming achieves the highest possible insulation value. Longevity is further improved through stainless steel interiors, which maintain temperature better[1], and, unlike painted steel, will not rust or corrode from heavy use with sample racks.

Liebherr ULTs offer a few additional features to make life easier for both delivery and maintenance, sidestepping some common lab headaches. Liebherr models are delivered with a ramp-system that negates the need for special forklifts. Defrosting is made more convenient with an integrated condensing-water tray.

Cost savings by technology and strategy

	Average Consumption kWh/day	Average Consumption kWh/year	Annual Energy Cost (at $0.1059 per kWh[4])	Lifetime Energy Cost*	Annual Temperature Reduction Energy Savings (37%)	Lifetime Temperature Reduction Energy Savings*	Annual Best Practices Energy Savings (30%)	Lifetime Best Practices Energy Savings*
Energy Star Freezer	13.75	5,019[3]	$531.51	$5,315.12	$196.66	$1,966.59	$159.45	$1,594.54
Standard Half-Life Freezer	24[2]	8,760	$927.68	$9,276.84	$343.24	$3,432.43	$278.31	$2,783.05
Standard New Freezer	17[2]	6,205	$657.11	$6,571.10	$243.13	$2,431.31	$197.13	$1,971.33
Liebherr 5001-70	8.142	2,972	$314.72	$3,147.17	$116.45	$1,164.45	$94.42	$944.15

*Assumes 10-year lifespan



An integrated service-reminder provides an optional countdown display and a notification message when service is due. Liebherr ULTs also offer as an accessory kit a CO_2-backup system connected to the appliance controller, which displays battery-backup or pressure-status/alarm information.

References

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2. Faugeroux, D. (2016) Ultra-Low Temperature Freezer Performance and Energy Use Tests. *Office of Sustainability, University of California, Riverside.* https://www.colorado.edu/ecenter/sites/default/files/attached-files/ucr_ult_tests_report_-_2016_final_df1.pdf

3. Office of Energy Efficiency & Renewable Energy. Purchasing Energy-Efficient Laboratory-Grade Refrigerators and Freezers. *Federal Energy Management Program.* https://www.energy.gov/eere/femp/purchasing-energy-efficient-laboratory-grade-refrigerators-and-freezers. [Accessed Feb 25, 2022]

4. U.S. Energy Information Administration. (2021) State Electricity Profiles. https://www.eia.gov/electricity/state/.

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