The Evolution of Cool

ULTRA-LOW TEMPERATURE FREEZER TECHNOLOGY IN PROGRESS

From the days of wooden boxes filled with snow or blocks of ice, to the 1800s when mechanical refrigeration systems were invented, people have stored and preserved their food using very archaic methods. It was not until the 1940s that the first free-standing freezer was introduced and since then, the freezer has made huge technological advancements to become an independent unit that plays a more significant role than just storing food.

Today, the freezer is as commonplace in the laboratory environment as it is in the home, and the need for precise refrigeration has grown considerably over the last few years. High performance ultra-low temperature (ULT) freezers are an essential piece of equipment in the laboratory, providing long-term protection and storage for valuable biological samples on a daily basis in industrial, clinical, and research applications worldwide. Therefore, protecting the integrity of samples is extremely important and can be achieved by combining rapid temperature recovery, temperature stability, and operational efficiency, all in a productive and comfortable lab environment.

However, for lab applications, not just any freezer will do and choosing the wrong one can be costly. A freezer door opened frequently or for extended periods of time could expose your samples to warm ambient air, creating an opportunity for decreased sample integrity. In addition, many lab professionals do not realize the consequences of storing valuable samples and materials, such as DNA, RNA, cells, and protein samples, in conventional household freezers. These units are not designed to maintain critical storage requirements demanded in most laboratory applications; inadequate systems result in wider temperature fluctuations, as well as uneven temperature distribution throughout the cabinet. Choosing a freezer that provides tight temperature uniformity and delivers rapid temperature recovery is vital in maintaining sample integrity.

KEEPING IT COOL

Freezing is a crystallization process which involves lowering the temperature below 0 °C, resulting in the gradual conversion of water into ice. This freeze-concentration process occurs as water freezes out of solution in the form of pure ice crystals, which causes the freezing temperature of the remaining solution to drop. Freezer cooling systems undertake this process by removing heat from the air in the unit rather than cooling the air in the freezer.

Ultra-low temperature freezers can maintain their internal compartments at temperatures as low as –86 °C (-123 °F) by combining the latest technology advancements to ensure the long-term preservation and storage of valuable samples. These sub-zero freezing temperatures are associated with the extended viability of preserved biological samples by dramatically reducing metabolic activity compared to –20 °C household freezers, thus directly influencing the time during which the samples can be recovered without damage.

COLD STORAGE TECHNOLOGIES

Freezer technology is now a conventional industrial technology that has recently achieved a high level of maturity worldwide due to the increased levels of laboratory pro-

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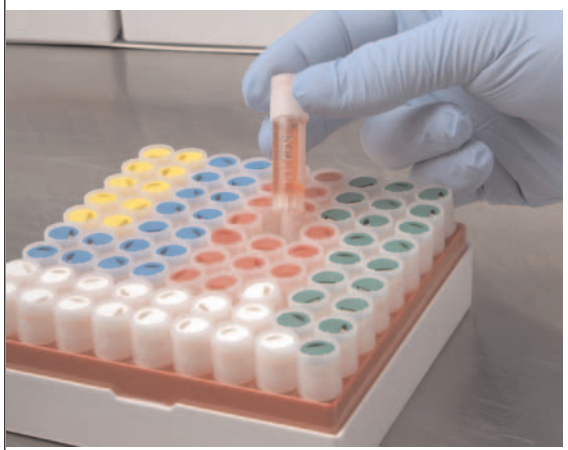
tocol regulations. Minimal fluctuations in temperature are critical to the viability and effectiveness of biomedical products so international regulatory bodies require laboratories to constantly monitor the temperature variation during the storage process. There is also a need for the cooling industry to develop cost-effective and environmentally sustainable solutions to increase energy efficiency. This means focusing on technologies, materials, and solutions that enable new cooling solutions to be delivered in an environmentally responsible manner to enable standards for safety and performance to be met.



As a result, innovative technological improvements have been introduced over the last few years in three key areas — temperature uniformity, recovery, and control. New refrigerant, vacuum insulation, and ultra-low temperature freezing technologies have resulted in the introduction of new products and systems to the market. ULT freezers are now designed to fulfill the toughest environmental and cost-saving targets and incorporate the latest technologies. These design advancements mean that they use less electricity, produce less heat, and make less noise — factors that create a more comfortable laboratory environment, result in cost savings, and operational efficiencies.

SUSTAINABLE COOLING

The basic components of today's modern freezer systems operate on a cooling concept adapted from Faraday known as a vapor-compression system. This involves compressing gas into a liquid that will then absorb heat and in doing so returns to gas. Advanced high performance ULT freezers are now designed with new generation patented refrigeration technology and use custom-designed compressors to maintain vital operating temperatures up to –86°C to provide the most accurate interior storage conditions possible.

Temperature recovery is an important feature of modern freezers for precise temperature control. Door openings dramatically influence temperature uniformity by creating frost, and prolonged or frequent use increases the temperature of internal compartments very quickly. Therefore, it is vital that freezers recover quickly before the brief rise in temperature and the formation of ice crystals compromise the samples. Forced-air refrigeration provides more heat removal capacity ensuring rapid temperature recovery after door openings. This cooling technology works very differently from household freezers and recovers its temperature much more quickly. This decreases the risk of sample degradation. In addition, highly developed robust electronics platforms feature easy-to-use microprocessor controls and provide real-time monitors and precise temperature settings, power, and other critical parameters, further ensuring the integrity of samples.

One problem with freezing is that it is an exothermic process, and the excess heat needs to be removed in some way in order to maintain controlled cooling. Advanced ULT freezers require less power to efficiently maintain cabinet temperatures which in turn reduces heat emissions into the lab environment, reduces air conditioning and energy costs, and maximizes operational efficiencies.

High performance ULT freezers comprise of an interior storage compartment that uses advanced noise abatement and super insulation technologies for more effective minimal noise output. These technological advancements mean that freezers are now a lot quieter, allowing units to reside directly in the lab. This speeds sample preparation and minimizes sample exposure to ambient air. Researchers, who spend many hours surrounded by lab equipment, also benefit from a quieter and more productive, efficient, and comfortable working environment.

Thermal insulation is achieved inside the freezer using super insulation, a vacuum formed panel consisting of multi-layers of glass fiber. This is encased by a non-gas permeable membrane to insulate the housing, which subsequently reduces freezer wall thickness from traditional foamed in place insulation. This compact footprint means that storage and laboratory space is no longer taken up because of thick layers of insulation. Tight door seals also prevent warm, moist air from entering the freezer so ice builds up more slowly and less defrosting is needed. This design is also effective in preventing energy from re-entering the freezer, thereby improving energy efficiency and in turn decreasing heat injection into the surrounding environment. When opening the doors, it can be difficult for the temperature to restabilize. In order to combat this,

freezers are fitted with inner doors made from an acrylonitrile butadiene styrene (ABS) polymer to reduce cold air loss. This makes it useful for storing material at critical temperatures and to balance cost, size, and capacity considerations.

Other advanced features of modern ULT freezers include a microprocessor temperature control system with digital temperature display, a platinum resistance sensor for extra precision and reliability, a power failure warning system with built-in audible and visible indicators, double insulation polyurethane walls, and hinged outer door latch. Various rack configurations are also available to help ensure the easy retrieval of samples and minimize exposure to ambient conditions.

KEEPING COOL WITH NEW TECHNOLOGIES

Modern refrigeration is almost entirely based on a compression/expansion cycle, which is a reliable and relatively low cost technology. Over the years, all parts of a conventional freezer have been considerably improved due to extended research, and many of the challenges associated with maintaining precise temperature control have been eliminated due to current advancements in control design and technology, as previously discussed.

However, new generation cooling technologies are emerging that are now focused on meeting higher energy efficiency standards and environmental compatibility which also consider criteria costs and functionality while phasing out chlorofluorocarbon (CFC) refrigerants. Freezers are constantly working and can use a lot of energy to achieve a uniform chamber distribution of temperature in well-insulated freezers. In addition, freezers consume the most energy in compensating for the heat that enters the cabinet through the insulation or gaps in the door seals. Energy efficient freezers represent a better investment and new technologies mean that freezers now use less energy and can be operated without ecologically harmful refrigerants and insulation materials. Over the next few years, energy efficiency, green solutions, and the total cost of ownership will be at the forefront. Finding substitutes for greenhouse-effect inducing fluids in energy processes is a major challenge in the struggle to reduce CO_2 emissions. CFCs damage the ozone layer and future cooling technologies lie with safe and effective alternatives such as natural substances that include hydrocarbons, CO_2, and ammonia. Efforts are also being directed to develop other types of refrigerants, which will be even more eco-friendly, cost effective, efficient, convenient, and reliable.

A CONTINUOUS COOL

Scroll compressors are becoming more common within refrigeration applications due to the reliability and compact size of the compressor's operating mechanism and reduction of moving parts. Instead of utilizing a valve and piston-driven motion to compress gas, the scroll compressor works with two mating parts that literally "scroll" together and rotate around each other. This advanced engineering and flow dynamics efficiently and smoothly compresses the refrigerant gas, and replaces approximately fifteen noisy high-wear parts.

A STIRLING IDEA

The Stirling freezer is based on the reverse of the Stirling engine in cycle and has attracted much attention because it needs less heat energy to generate power and does not require any refrigerant harmful to the environment. Stirling engine technology approaches the limits set by the laws of thermodynamics more closely than any other system and is now being developed for generating low temperature states as low as cryogenic temperatures.

The Stirling engine has been studied and developed as one kind of gas compressor expander because it theoretically has a very high thermal efficiency, allows the use of various kinds of heat sources other than petroleum, and is quiet and harmless to the public.

CONCLUSION

It can be said that these emerging technologies allow for all ultra-low temperature applications and are well suited for use in laboratories and hospitals for the long-term preservation and storage of samples, specimens, and components. These types of valuable samples are protected by combining great rapid temperature recovery, temperature stability, and operational efficiency, all in a productive and comfortable lab environment. These innovations will usher in a new era in ULT freezers allowing for quiet, compact, high efficiency designs to become standard in the industrial and biomedical industries.

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