TECH NOTE

# How to Build an Ultra-Low Temperature "Safe" for Biological Samples?

## Technical Analysis of the Snorkel Automated ULT Freezer's Dual-System Two-Stage Cascade Refrigeration

Genepoint

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# Background

Ultra-low temperature (ULT) freezers function as "low-temperature protection chambers" for critical scientific research materials, including biological samples and experimental reagents. The stability and reliability of their refrigeration systems directly impact the safety of sample storage. Maintaining a consistently stable ULT environment below -80°C for extended periods, as well as the ability to respond effectively to unexpected events such as sudden failures and power outages, are key factors researchers consider when selecting ULT freezers.

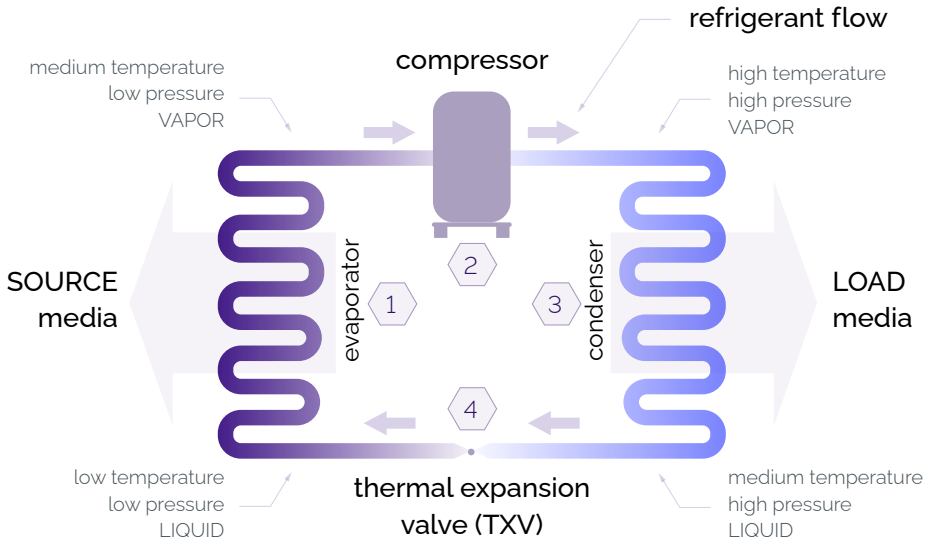



**Figure 1.** In a basic refrigeration cycle, the compressor drives the refrigerant flow to enable cooling.

Currently, there are three mainstream refrigeration methods used in the industry to achieve ULT environments below -60℃: the Cascade Refrigeration Cycle (CRC), the Auto-cascade Refrigeration Cycle (ARC), and the Joule-Thomson Refrigeration Cycle (J-T). These methods differ significantly in structural design, refrigerant selection, operational reliability, and other factors, all of which directly impact the user experience and the safety of sample storage. Below, we analyze the core principles, advantages, and disadvantages of each method and explain why the "dual-system two-stage cascade refrigeration" approach is considered the safest option for preserving biological samples.

# Mainstream Industrial Refrigeration Systems

## (I) Cascade Refrigeration Cycle (CRC) — A Mature and Stable "Classic Scheme"

The core principle of the cascade refrigeration cycle is "relay cooling": it divides the large temperature difference involved in cooling from room temperature to below -80℃ into two smaller temperature differences. These are managed separately by two compressors—the high-temperature stage and the low-temperature stage—similar to two players in a relay race performing their respective roles and working together efficiently.

### Core Configuration

The system includes two dedicated compressors: the high-temperature stage is designed for R290 refrigerant, while the low-temperature stage is designed for R170 refrigerant. There is no complex separation device; heat exchange between the two stages is achieved solely through a cascade heat exchanger.

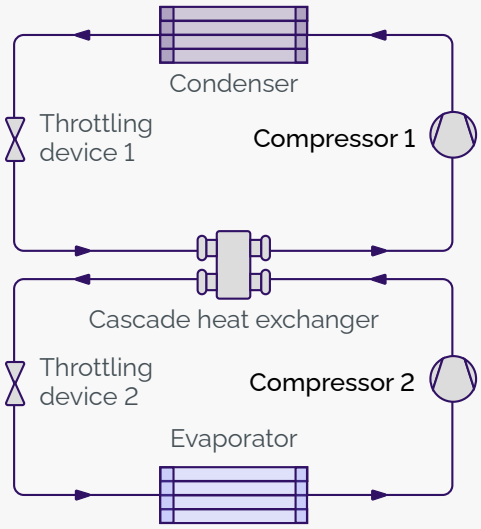



Figure 2. CRC features two compressors and a cascade heat exchanger for ULT cooling.

### Key Advantages

1. **Mature and reliable technology:** As the longest-used and most widely applied ULT refrigeration system, it has fostered the development of a dedicated component system across the upstream and downstream supply chains. All components are custom-designed for this system and have been validated through extensive market testing, demonstrating exceptional stability.

2. **Single system meets requirements:** No additional backup system is needed. A single cascade refrigeration cycle can reliably maintain a temperature below -80℃ for extended periods, featuring a simple structure and robust performance.

3 **Convenient maintenance and low cost:** This system uses pure refrigerants such as R290 and R170, which are readily available on the market and do not require custom production by freezer manufacturers. Compared to mixed refrigerants, replacement during maintenance is faster, significantly reducing downtime and maintenance costs.

Currently, most embedded freezers, manual freezers, and other products with specific space and cost requirements in the industry prefer this design. Genepoint's Samplock ULT freezer features a classic two-stage cascade refrigeration system, offering a balance of stability and practicality.

## (II) Auto-Cascade Refrigeration Cycle (ARC) — A Compromised "Backup-Dependent Scheme"

The core of the auto-cascade refrigeration cycle is "achieving multiple effects with a single compressor": it uses one compressor combined with a gas-liquid separation device and progressively cools the mixed refrigerant through different components to ultimately achieve ultra-low temperatures.

### Core Configuration

It consists of one general-purpose compressor (no dedicated adapted model), a gas-liquid separation device, and two throttling capillaries, all relying on mixed refrigerants. Different manufacturers use various formulas, with no unified standard.

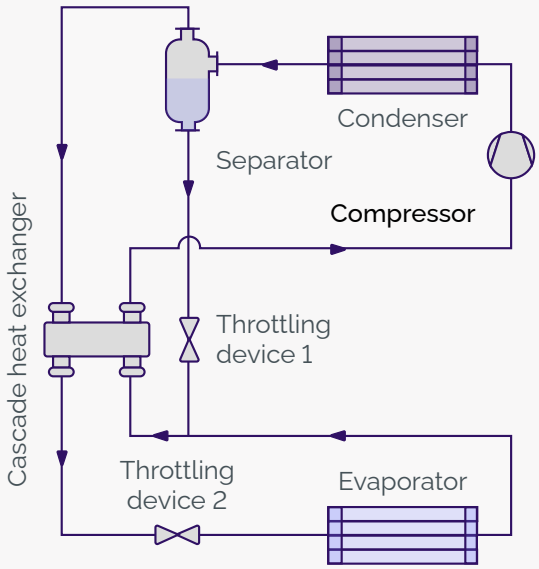



Figure 3. ARC features a general-purpose compressor and dual throttling devices for ULT cooling.

### Key Limitations

1 **Innate lack of reliability:** There are no dedicated compressors or refrigeration components specifically designed for mixed refrigerants. As a result, only conventional components with similar functions can be used as substitutes, leading to poor adaptability and high failure rates during long-term operation.

2. **Maintenance Dependent on Manufacturers:** Mixed refrigerants are proprietary formulas owned by manufacturers. During maintenance, they can only be purchased from the original manufacturer, which not only incurs high costs but may also result in prolonged downtime of the refrigeration system due to extended supply lead times.

3. **Dependence on Dual-System Backup:** To compensate for reliability issues, all ARC products on the market employ a "dual-system design—one for operation and one for backup". However, to reduce costs, manufacturers often lower the specifications of each individual system (such as decreasing compressor displacement and condenser size), which limits a single system's ability to achieve a minimum temperature of only -70℃ to -80℃ during operation. Therefore, both systems must operate simultaneously to consistently maintain temperatures below -80℃.

## (III) Joule-Thomson Refrigeration Cycle (J-T) — A High-Pressure, High-Load "Risky Scheme"

The Joule-Thomson refrigeration cycle, also known as the "internal cascade cycle" ,uses a single compressor and one throttling device, combined with a mixed refrigerant containing numerous low-boiling components, to achieve ultra-low temperatures through the throttling effect under high pressure.

### Core Configuration

One general-purpose compressor and one throttling capillary (or dedicated throttling device) are used, with a high proportion of low-boiling components in the mixed refrigerant.

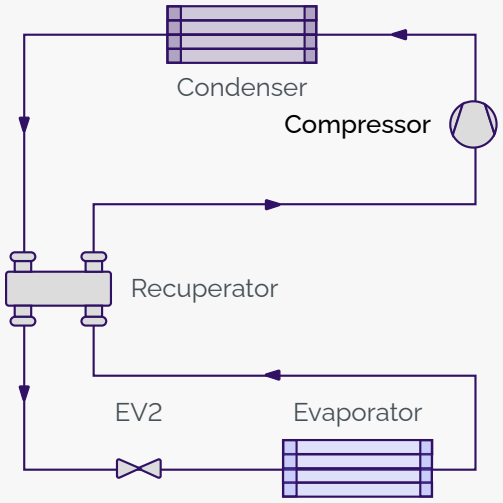



Figure 4. J-T features a single compressor and a throttling valve (EV2) for ULT cooling.

### Key Risks

1. **Extremely high system pressure:** Low-boiling refrigerants generate ultra-high pressure during startup and operation, causing the compressor to operate in an overloaded state for extended periods. This results in rapid wear and a significantly higher failure rate compared to other systems.

2. **No dedicated adapted components:** Similar to the ARC scheme, mixed refrigerants do not have dedicated compressors and components specifically designed for them. As a result, only substitute parts can be used, which further reduces system reliability.

3. **The dual-system design still has limitations:** it requires a "dual-system backup" configuration, but the capacity of each individual system is reduced (for example, insufficient compressor power), limiting the achievable temperature range to approximately -70℃ to -80℃. To maintain storage temperatures below -80℃, both systems must operate simultaneously. Furthermore, under high-pressure conditions, even with a backup system, the risk of sudden failures remains higher than that of a cascade refrigeration cycle.

## Common Industry Challenges of Current Mainstream Refrigeration Solutions

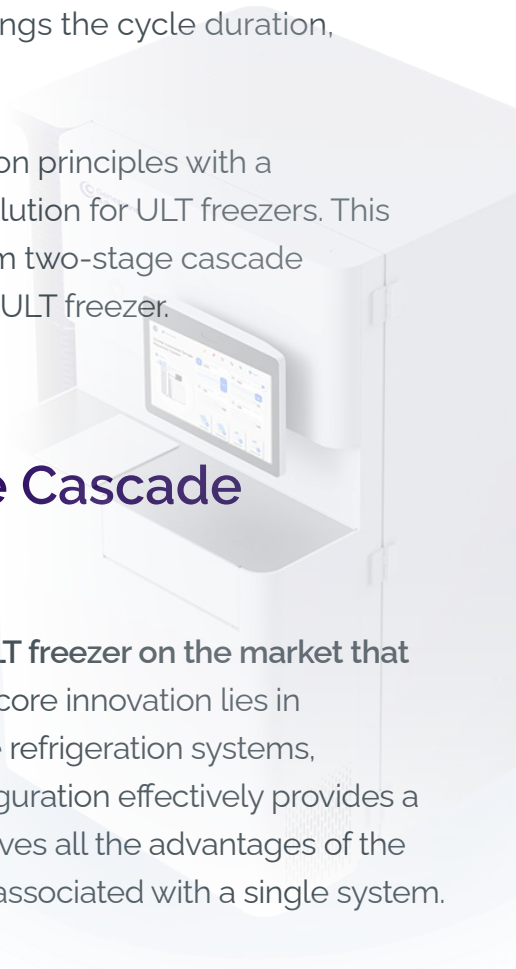
Through the analysis of the three mainstream schemes, we can identify the core contradictions commonly present in the industry.

1. Due to their reliance on mixed refrigerants and the absence of dedicated components, ARC and J-T schemes inherently suffer from insufficient reliability, which can only be mitigated by implementing dual systems. However, to control costs, the configuration of a single system is simplified, leading to situations where a single system fails to meet requirements and dual systems are barely adequate.

2. The traditional CRC scheme offers strong stability within a single system but lacks a backup mechanism. Consequently, sudden failures may cause temperature fluctuations in the sample storage environment.

3. The exclusive formula attribute of mixed refrigerants increases the maintenance costs of ARC and J-T schemes and prolongs the cycle duration, thereby hindering scientific research progress.

Therefore, the combination of mature and stable refrigeration principles with a dual-system backup guarantee has become the optimal solution for ULT freezers. This approach is precisely the core logic behind the "dual-system two-stage cascade refrigeration" scheme employed by the Snorkel automated ULT freezer.



## Snorkel's Dual-System Two-Stage Cascade Refrigeration Technology

**The Snorkel automated ULT freezer is currently the only ULT freezer on the market that utilizes a dual-system two-stage cascade refrigeration.** Its core innovation lies in integrating two completely independent two-stage cascade refrigeration systems, comprising a total of four dedicated compressors. This configuration effectively provides a "dual safety guarantee" for sample storage. It not only preserves all the advantages of the traditional CRC system but also eliminates the backup risks associated with a single system.

### (I) Core Advantage: Four Compressors with Dual Independent Systems, Maximizing Safety and Redundancy

Each two-stage cascade system consists of two dedicated compressors: a high-temperature stage and a low-temperature stage. These two systems operate independently and do not interfere with each other, utilizing a "one in use, one on standby" mode of operation.

1. During daily operation, one system is primarily responsible for refrigeration, while the other system remains on standby, continuously monitoring the status of the main system in real time.

2. In the event of a sudden failure of the main system, the backup system will automatically activate instantly, seamlessly taking over the refrigeration process. This ensures that the temperature inside the freezer remains consistently below -80℃, effectively preventing sample loss due to refrigeration interruptions.

3. Both systems utilize the mature design of the CRC scheme, allowing a single system to reliably meet requirements without depending on the "simultaneous operation of dual systems" as seen in ARC and J-T, thereby further enhancing operational reliability.

## (II) Detailed Guarantee: Comprehensive Full-Link Monitoring and Customized Components to Enhance Stability

In addition to the core dual-system design, Snorkel implements multiple detailed measures to optimize and ensure the long-term stable operation of the refrigeration system.

1. **Real-time status monitoring:** Temperature and pressure sensors are installed at key points on the four compressors The controller captures operational data in real time and promptly adjusts the refrigeration output according to load variations, preventing temperature fluctuations caused by changes in load.

2. **Refrigerant Purification Guarantee:** Equipped with a dedicated, customized dry filter that continuously purifies the refrigerant in the cycle, preventing impurities from reducing heat exchange efficiency and compressor lifespan, thereby ensuring the long-term efficient operation of the refrigeration system.

3. **Exclusive Production Process:** At Genepoint's Taicang Global Strategic Industrial Base, Snorkel operates a dedicated production line optimized for the assembly of the dual-system two-stage cascade refrigeration system. This specialization enhances the assembly accuracy and reliability of the refrigeration system.

## (III) Additional Value: Energy Conservation and Emergency Response, Balancing Environmental Protection with Crisis Management

1. **Energy Conservation and Environmental Protection:** Adopting R290 and R170 hydrocarbon refrigerants that comply with global energy conservation and environmental protection standards. Compared to traditional refrigerants, these offer a 15% to 35% improvement in energy efficiency, which not only reduces operational costs but also minimizes environmental impact.

2. **Optional Liquid Nitrogen Backup System:** Supports an optional liquid nitrogen backup system. In extreme situations, such as sudden power outages, the liquid nitrogen system can automatically take over refrigeration from the compressor, providing a dual emergency guarantee of "electricity + liquid nitrogen" and ensuring the safe storage of samples under any unexpected circumstances.

## Snorkel: The "Top-Tier Safe" for Biosamples

The core value of an ULT freezer is to provide an absolutely stable and completely safe storage environment for biological samples. Snorkel's dual-system, two-stage cascade refrigeration design is centered around this principle.

1. Based on the mature principles of the CRC scheme, dedicated components and pure refrigerants ensure the fundamental stability and ease of maintenance of the refrigeration system.

2. The innovative dual independent system design eliminates the backup risks associated with a single system and offers industry-leading safety redundancy.

3. Detailed designs, such as full-link monitoring, customized components, and liquid nitrogen backup, further reinforce the "safety line" for sample storage.

For scientific research institutions and enterprises that prioritize absolute safety and cannot afford the risk of sample loss, the dual-system, two-stage cascade refrigeration technology of the Snorkel automated ULT freezer is undoubtedly the optimal solution for ULT storage of biological samples. This technology ensures that every valuable sample is securely preserved for extended periods under the protection of dual safeguards.

# About Genepoint

Genepoint Technologies is committed to providing innovative, automated, intelligent, and comprehensive storage solutions for biological samples. We focus on independent research and development, ensuring full control over the entire R&D and production process.

Upholding the mission of "Inspire Life Exploration", Genepoint consistently pushes technological boundaries and advances the practical applications of life sciences and biomedicine through ongoing innovation.

Genepoint is headquartered in Shanghai and has production, R&D, and product operation centers in both China and Singapore.

For more information, please visit **www.genepoint.com** or email us at **info@genepoint.cn**.