Thermo Scientific Forma® Lab Refrigerators/ Freezers Provide Advanced Refrigeration Systems to Maintain Stable Temperature

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Key Words

- Refrigerator
- Freezer
- Validation
- Stability
- Storage
- Temperature

Advanced Refrigeration White Paper

Abstract

Precise refrigeration has long been critical to maintain storage protocols in the laboratory environment. The most stringent requirements for refrigeration systems are generally found in laboratories performing blood and blood product manufacturing; tissue culture, including human reproductive technology; molecular biology and protein chemistry; drug development; environmental biology; and food safety. While the need for refrigerated equipment is a requirement for nearly all laboratories, many lab professionals do not realize the consequences of storing valuable samples, reagents, and materials in equipment designed for commercial or household applications. Inadequate refrigeration systems result in wider temperature fluctuation as well as uneven temperature distribution throughout the cabinet. Thermo Scientific Forma® Lab Refrigerators/ Freezers are designed to meet the demanding needs of the laboratory environment. We combine expertly designed controls, a mechanically circulated air system, and rugged cabinet construction to ensure that precise temperature recovery and uniformity are maintained throughout the life of the product.

Critical Storage Requirements for Biologics

More than one decade ago, researchers discovered that small variances in temperature played a role in the degradation and loss of function of animal tissue samples. A 1991 study conducted at the University of Alberta demonstrated that the viability of rat Islet cells significantly decreased after preservation at refrigerated temperatures with temperature fluctuation of only ±3C.[1] More recently, researchers studied the effect of temperature variability on spermatozoa samples from various animal species.[2,3] Significantly higher fertilization rates were recorded for samples that remained above 0C (32F), thus, suggesting the implementation of critical storage parameters for valuable genetic samples.

In 2001, the Philadelphia Department of Health inspected 342 citywide medical practices to determine whether or not their vaccines were being stored properly. The results of this survey may astound you:

- 26% of providers were using inadequate freezers to store vaccines
- 29% carried expired vaccines in their refrigerators and freezers
- 3% were storing their vaccines at inappropriate refrigerator temperatures

Because of these statistics, the National Immunization Program at the Centers for Disease Control (CDC) instituted guidelines regarding reliable vaccine storage among physician's offices.[4,5] A summary of these guidelines is provided in table 1.

Storage Requirement	Vaccine	Shelf Life
Refrigerated, 2°C to 8°C (35.6F to 46.6F) Do not freeze.	DTaP DTaP/ACTHIB DTP DTP/HIB HBIG Hepatitis Vaccine HiB HBCV Influenza Vaccine influenza season IPV Lyme Vaccine MMR Vaccine MR Vaccine Meningococcal Vaccine Pneumococcal Vaccine Td-Adult DT-Pediatric	Up to 18 months Up to 1 year Up to 3 years Up to 2 years Use within current Up to 18 months Up to 24 months Up to 2 years Up to 18 months Up to 2 years
Frozen, colder than -15°C (5F) Do not thaw.	Varicella Vaccine	Up to 18 months

Precise temperature control is critical not only to the biomedical industry but to the food industry as well. Scientific evidence now supports the importance of maintaining a critical temperature range in the storage of food and agricultural products. Precise temperature control is vital to minimizing bacterial growth in food that will be distributed to consumers. Today, food producers and distributors are taking special precautions to ensure that food is delivered safely to the end consumer.

Regulations and Requirements

Because fluctuations in temperature can be so critical to the viability and effectiveness of biomedical and agricultural products, international regulatory bodies require laboratories to constantly monitor the temperature variation during the storage process. We develop products to meet the ever-changing regulations and requirements of these agencies to ensure that the customer remains in compliance with these factors.

Unlike other laboratory equipment manufacturers, we consistently evaluate and design equipment to meet the requirements of the Food and Drug Administration (FDA), American Association of Blood Banks (AABB), International Committee for Harmonization (ICH), and United States Department of Agriculture (USDA).

FDA

The FDA strictly regulates the daily activities and processes of blood banking and drug manufacturing centers.[6] Because products intended for human use must be stored at very precise temperatures, regulatory bodies have vastly shaped the daily processes and protocols followed by these laboratories. National blood centers, such as the American Red Cross, are required to constantly monitor the storage temperature of all of their blood products. Should the FDA determine that storage temperatures have fallen outside the acceptable range, the entire amount of product stored within the unit must be destroyed.

In 1995, the FDA implemented another system of control called the Hazard Analysis and Critical Control Point (HACCP).[7] This system was designed to monitor the food production industry to ensure that bacterial contamination resulting from poor food processing methods is reduced. Monitoring product temperature throughout the production process is a key element of these new regulations.

AABB

The AABB is a non-profit organization that sets stringent guidelines for the blood banking industry. The guidelines are designed to teach individual facilities how to formulate their own protocols to ensure compliance with standard blood handling and processing procedures. The AABB annually produces a comprehensive technical manual that complements the requirements of the FDA.

ICH

The ICH is a joint initiative involving regulators and industry participants as equal partners in the scientific and technical discussions of the testing procedures required to ensure and assess the safety, quality, and efficacy of medicines.

The ICH focuses on the technical requirements for medicinal products containing new drugs. The majority of these products are developed in Western Europe, Japan, and the United States; therefore, the committee's primary focus is to harmonize the development processes of these regions. To this end, a representative of the FDA resides on the committee and is directly involved in the communication process.

Refrigeration design plays a direct role in stability testing of new drugs. Since the ICH recommends a very tight validation specification for the refrigerators and freezers used during these studies, many organizations are looking to equipment manufacturers to meet the stringent requirements. Our Forma Lab Refrigerators/Freezers are specifically designed to meet the critical storage requirements of the ICH.

USDA

The USDA Food Safety and Inspection Service ensures that food and agricultural products intended for public consumption are processed and distributed according to proper food handling protocols.[8] Of highest concern are the transportation and handling of meat and egg products. In fact, in August of 1997, new federal regulations were put into place to ensure that all shell eggs packed for consumer use must be stored and transported at an ambient temperature not to exceed 45F (7.2C).[9] Violating organizations will be cited, and civil and criminal penalties may be enforced for repeat offenders.

The trend of increased regulation for blood, drugs, vaccines, and food products is sure to continue over the next decade. As international distribution of medicines and food products continue to rise, it becomes critical to ensure that these products are stored at stable temperatures and arrive safely to their destination in other countries.

Deficiencies in Commercial Refrigeration Products

Due to the increased levels of laboratory protocol regulation across the industry spectrum, it becomes increasingly important to inform lab managers and engineers of the risks associated with using commercial refrigeration systems for laboratory applications. The third section of this report provides valuable information regarding the deficiencies of commercial and household refrigeration products in three key areas: temperature uniformity, temperature recovery, and temperature control.

Temperature Uniformity

Conventional residential and commercial refrigerator/freezer units are commonly used in laboratories for short-term storage of critical products and materials. These units are often less expensive; however, they are not designed for precise temperature control and distribution. Figure 1 depicts the typical temperature distribution within the chamber of a residential refrigerator/freezer.

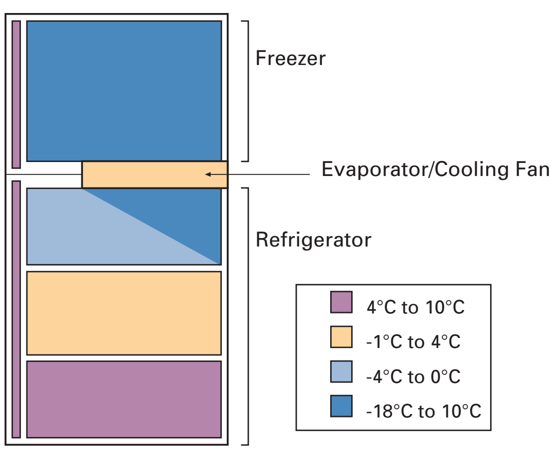

figure 1–Temperature distribution within a typical household refrigerator

Conventional refrigerators are not designed to provide uniform temperature distribution throughout the unit. A single cooling fan and evaporator are utilized to cool down both the refrigerator and freezer compartments.

Only one fan and evaporator are used to cool down both the refrigerator and freezer compartments in the residential unit. While the coldest air is channeled into the upper freezer compartment, the top portion of the refrigerator compartment is affected by the cooling system. The storage temperature can reach well below freezing on the top shelf of the refrigerator.

The second shelf of the refrigerator will generally hold an appropriate temperature range for most laboratory applications; however, the lowest shelf (farthest away from the cooling mechanism) can reach elevated temperature levels that will damage important samples, drugs, and reagents required for laboratory assays. When you consider that only one-third of the refrigerated compartment can be relied upon to provide adequate storage temperatures, the initial cost savings no longer exists!

In another example, a commercial-style, auto-defrost laboratory freezer was evaluated to quantify temperature fluctuation above a critical point of -15C (5F) during a single defrost cycle. The results of this analysis are depicted in figure 2.

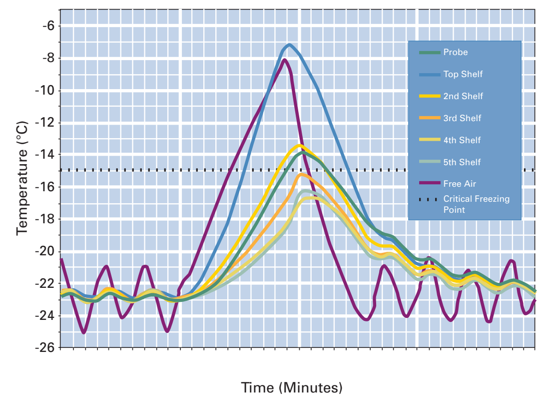

figure 2–Temperature readout during the defrost cycle from a commercial freezer

Weighted thermocouples were placed on 5 different shelves in a commercial freezer cabinet. At a temperature setting of -22C (-7.6F), readings were taken every 5 minutes to monitor temperature fluctuations above the critical freezing point of -15C (5F). Samples on the top shelf of the unit closest to the evaporator reached temperatures as high as -9C (15.8F). Temperatures remained above the critical freeze point for more than 45 minutes during a single defrost cycle.

These results show that the temperature of samples on the top two shelves (located closest to the fan/evaporator) rose above the critical storage requirement during the defrost cycle. Fluctuations in temperature of this severity will likely send a unit into alarm and will destroy valuable samples and products. While this unit may be less expensive than more advanced freezer designs, the effective storage capacity is dramatically reduced because the top two shelves cannot be used to store product.

Temperature Recovery

Temperature recovery is another important feature to precise temperature control in the laboratory environment. Door openings dramatically influence the temperature uniformity with a refrigerator or freezer unit. Prolonged or frequent openings will increase the internal compartment temperatures very quickly, often resulting in setting the unit off into alarm. Therefore, it is vital that laboratory equipment recover the temperature setpoint quickly, before brief rises in temperature affect product storage.

The relationship of temperature recovery and performance to cabinet design is vastly dependent upon the type of cooling system inherent to the unit. The two most common cooling methods to consider are Cold-Wall Refrigeration/Manual Defrost and Forced-Air Refrigeration/ Automatic Defrost.

The **Cold-Wall cabinet** design provides a stable temperature environment for long-term product storage. This design eliminates the need for a regular defrost cycle, eliminating the brief increases in temperature commonly seen in commercial cabinets.

The Cold-Wall cabinet design is not able to recover as quickly after extended door openings (figure 3). The air is cooled through conduction and natural convection with the cold wall. Temperature recovery generally occurs over a longer period of time. This rise in temperature could be detrimental to products stored in the center of the cabinet.

Product load in the cabinet also affects how quickly the cabinet returns to setpoint. The cold product cools the air around it and speeds up temperature recovery.

The **Forced-Air Refrigeration cabinet** works very differently. Warm air is cooled as it passes over an evaporator coil via a cooling fan. The cooling fan quickly distributes the cool air throughout the cabinet (figure 4). After frequent or extended door openings, this type of cabinet will recover its temperature much more quickly than a Cold-Wall design cabinet. However, this type of cabinet generally requires the addition of regular defrost cycles to remove the frost that naturally builds up on the evaporator coils near the fan. If special precaution is not taken to properly design the defrost cycle, the result is a temperature spike as shown in figure 2.

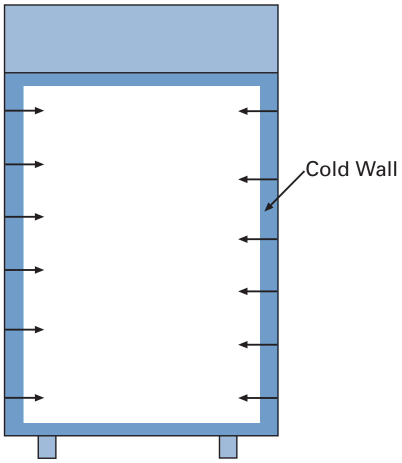

figure 3–Cold-Wall design

Temperature recovery is reduced in a Cold-Wall design cabinet after extended or frequent door openings.

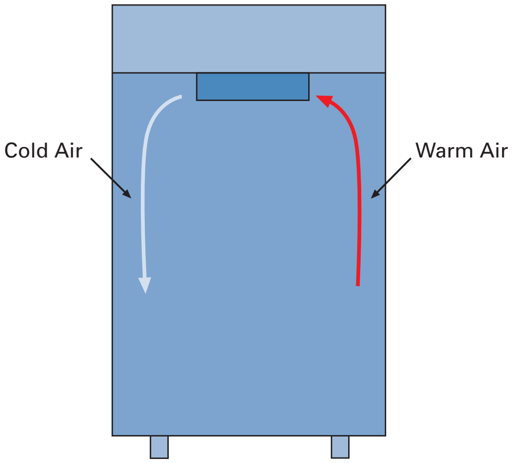

figure 4–Forced-Air design

Temperature recovery is enhanced in a Forced-Air design cabinet. Temperature uniformity is maintained after repeated or extended door openings.

Temperature Control Technology

Control technology for refrigeration systems is rapidly evolving to meet ever-changing laboratory requirements. Many of the challenges associated with maintaining precise temperature control are eliminated because of advancements in control design and technology.

Residential and commercial units typically offer temperature control through a manual dial thermostat. The customer is usually required to set cabinet temperature based on a numerical dial or a high/low designation.

We have taken great care to control the temperature rise during the defrost cycles associated with the Forced-Air cabinet design of our Forma Lab Refrigerators/Freezers. The control mechanism regulates the defrost cycle by turning on and off as temperature changes are detected. The end result is a continuous defrost cycle that minimizes cabinet temperature fluctuation while constantly removing the frost layer that will inhibit the evaporator coil's effectiveness. Custom products can be designed to completely remove any effects of the defrost cycle.

Conclusion

Conventional household refrigerators/freezers are not designed to maintain the critical storage requirements demanded of most laboratory applications. Our expertise and solutions in the field of cold storage and equipment can best meet your ever-changing needs of precise refrigeration.

End Notes

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