GLOBAL COLD CHAIN ALLIANCE®

05/12/2023

Best Practices in Food Tempering, Chilling and Freezing

Presented by: Robert Hernandez

GLOBAL COLD CHAIN FOUNDATION

USDA

Speaker

- United States Cold Storage
  - 44 Facilities, 13 States
  - ≈32 Billion pounds / 14 billion Kilograms Handled Annually
  - Monthly Inventory ≈ 2 Billion Pounds / 900 Million Kilos
- Career History
  - 17 Years of Industry Experience
  - Shipping & Receiving
  - Customer Service
  - Continuous Improvement & Training
  - Operations Management
  - Facility Design / Start up
  - Director, Northern California

Agenda/Course Goals

- Food Freezing Processes
- Food Tempering Processes
- Storage and Frozen Food Quality
- Questions??

Food Freezing Processes

Food Freezing Processes

- Introduction

1) Freezing provides extension of food product shelf-life

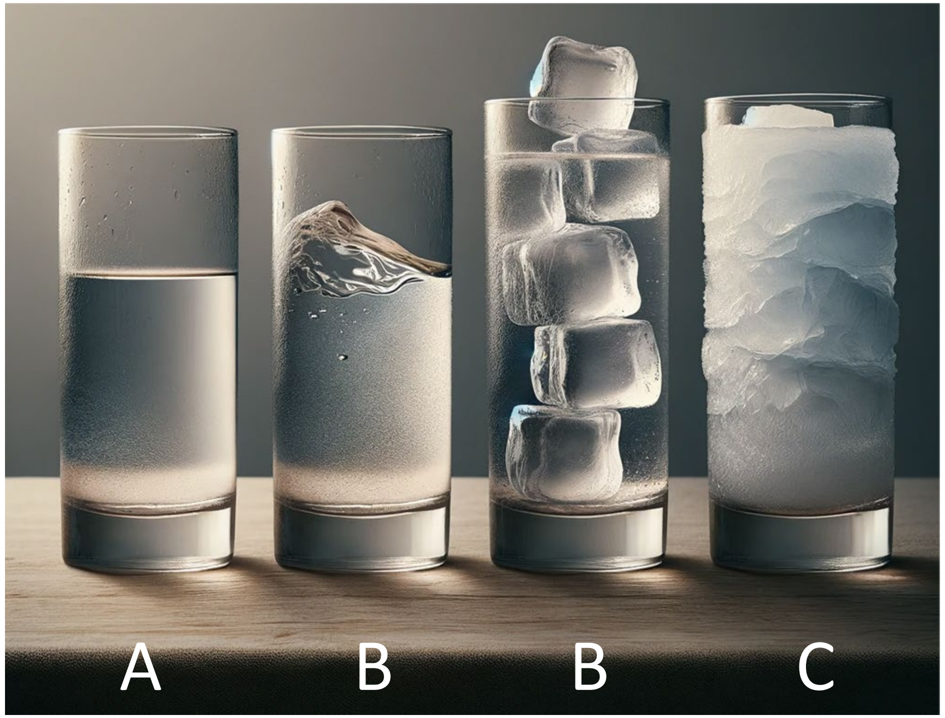
2) Process reduces product temperature sufficient to create phase change for water within product structure

3) Shelf-life extension depends on maintaining reduced storage temperature during storage

Typical Time/Temperature Freeze Graph
With Typical Values

3°C — A. Typical Initial Product Temperature

0°C — B. Product Freeze Point Temperature

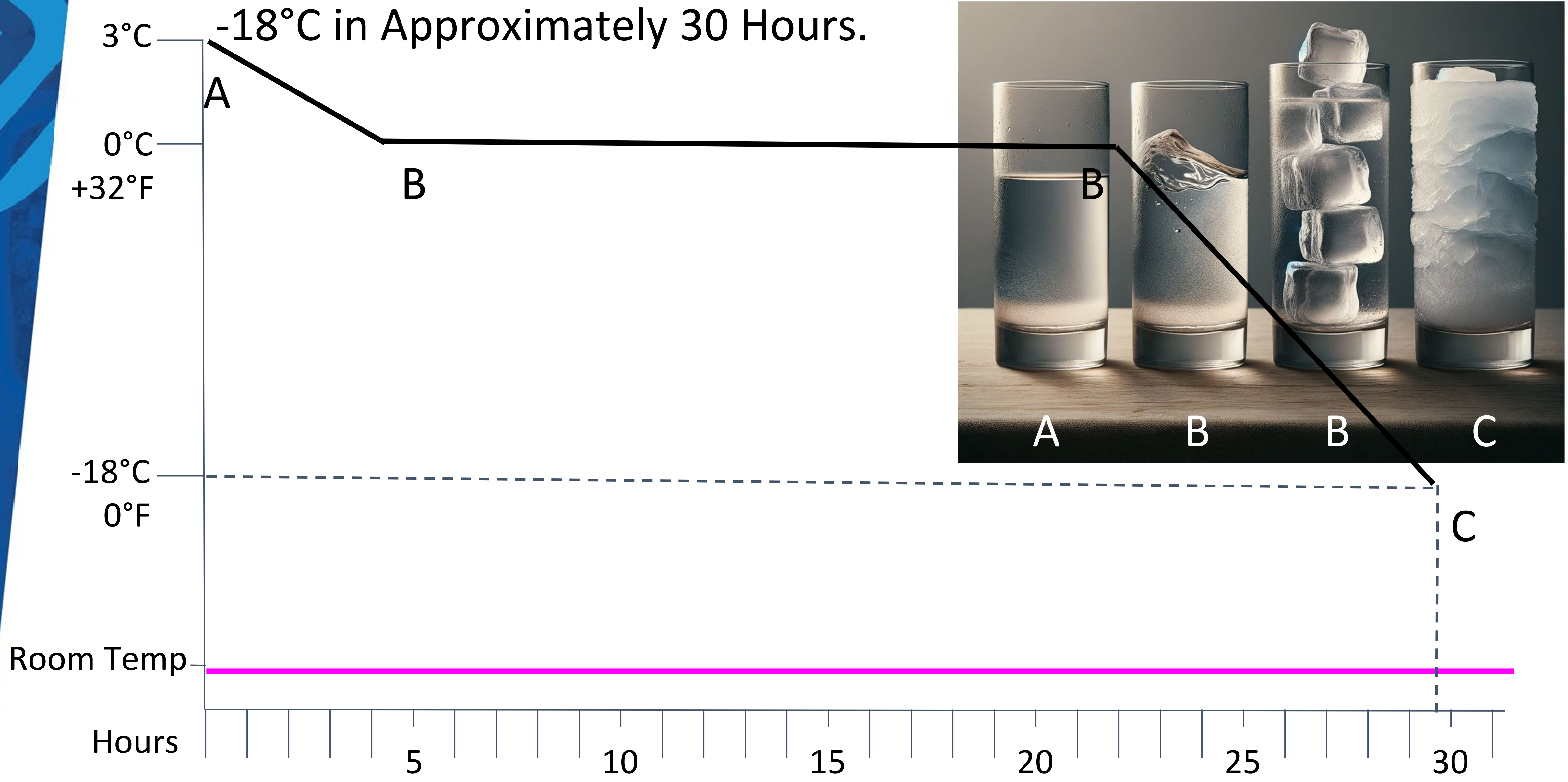


-18°C — C. Product “Target” Temperature

Room Temp — Example Room Temperature

Hours → 5 10 15 20 25 30

Typical Time/Temperature Freeze Graph
Product Temperature Goes From 3°C to -18°C in Approximately 30 Hours.



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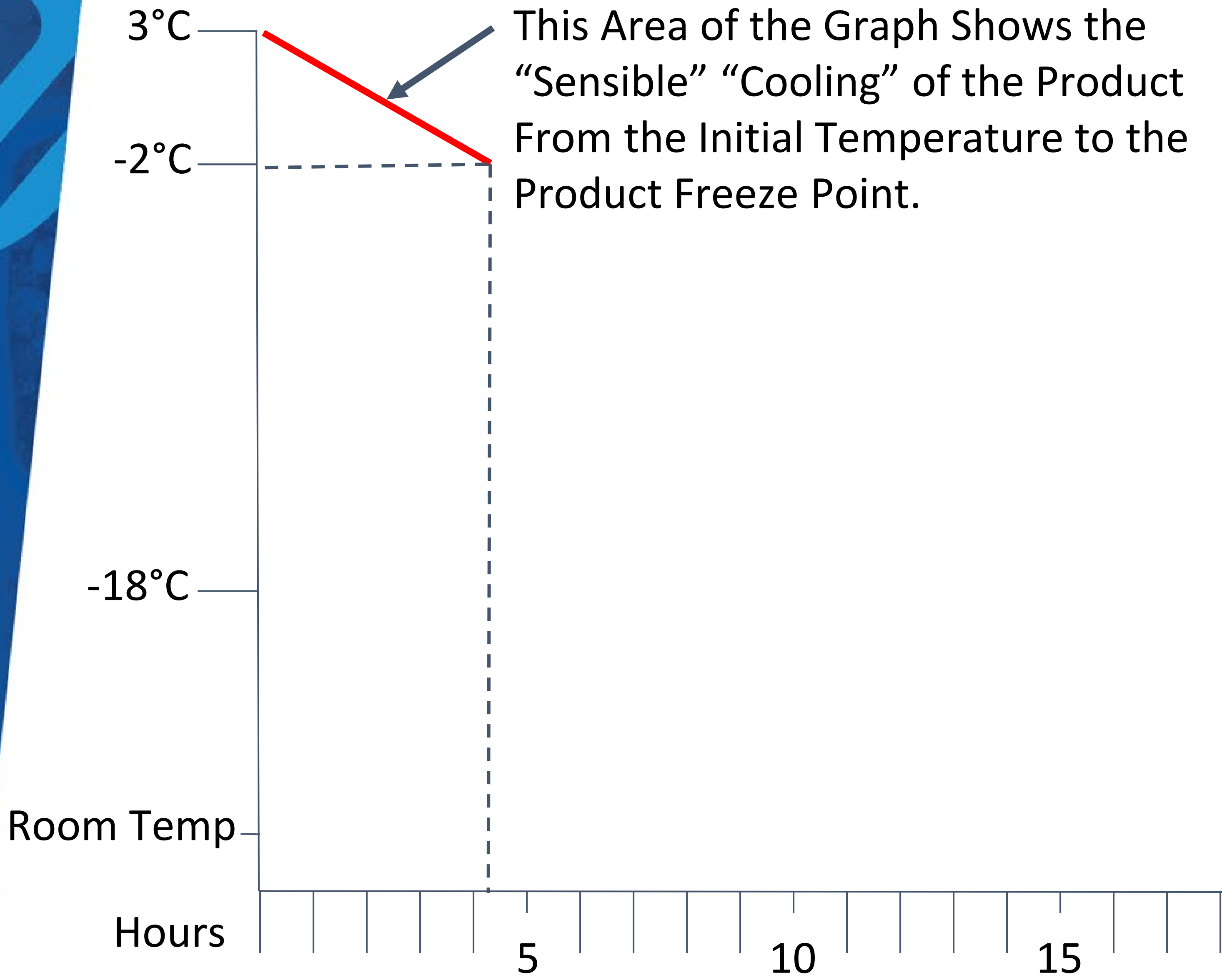

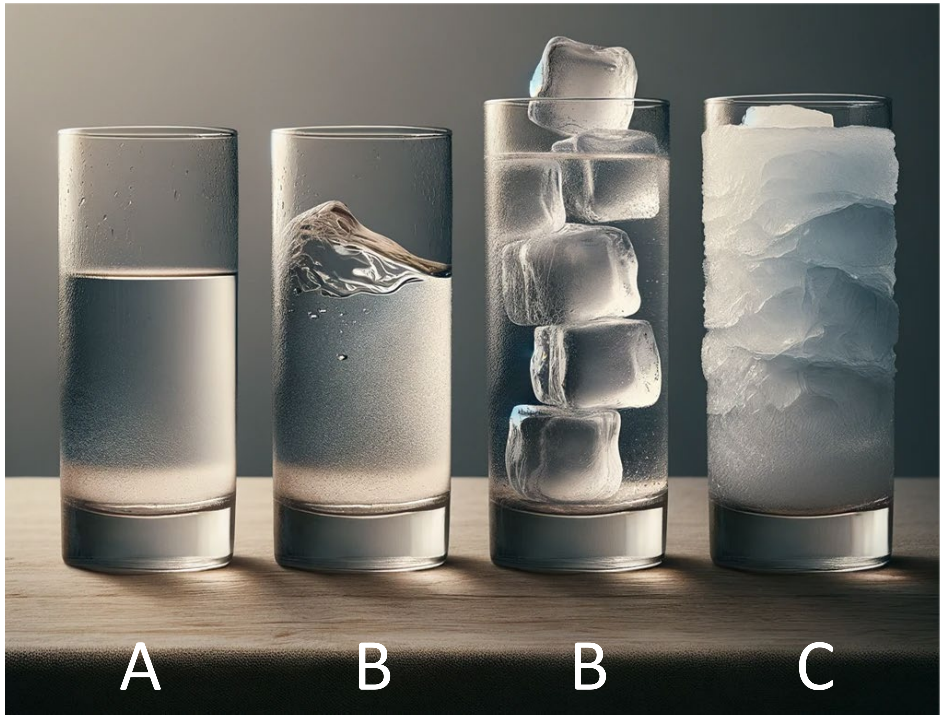

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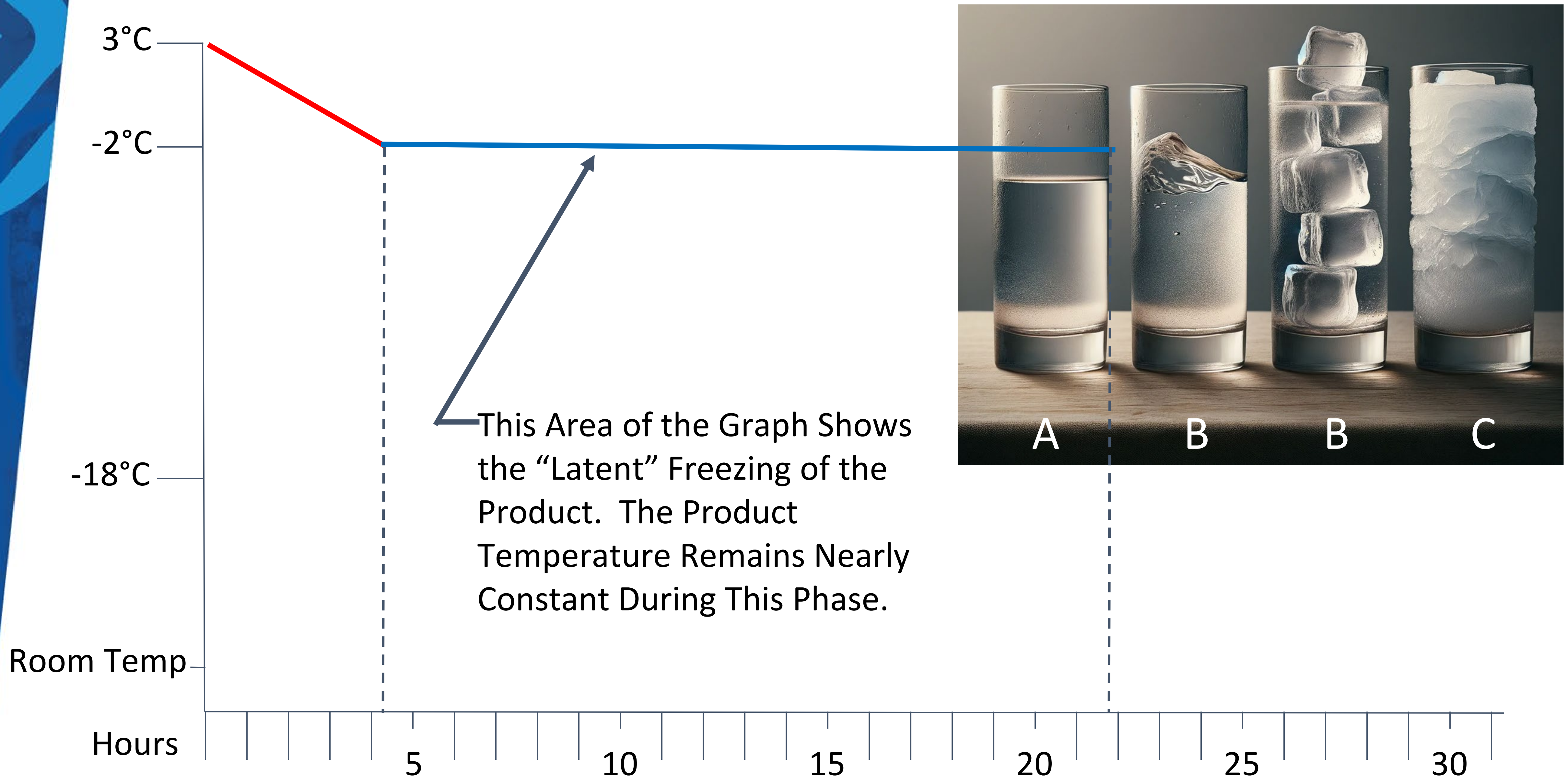

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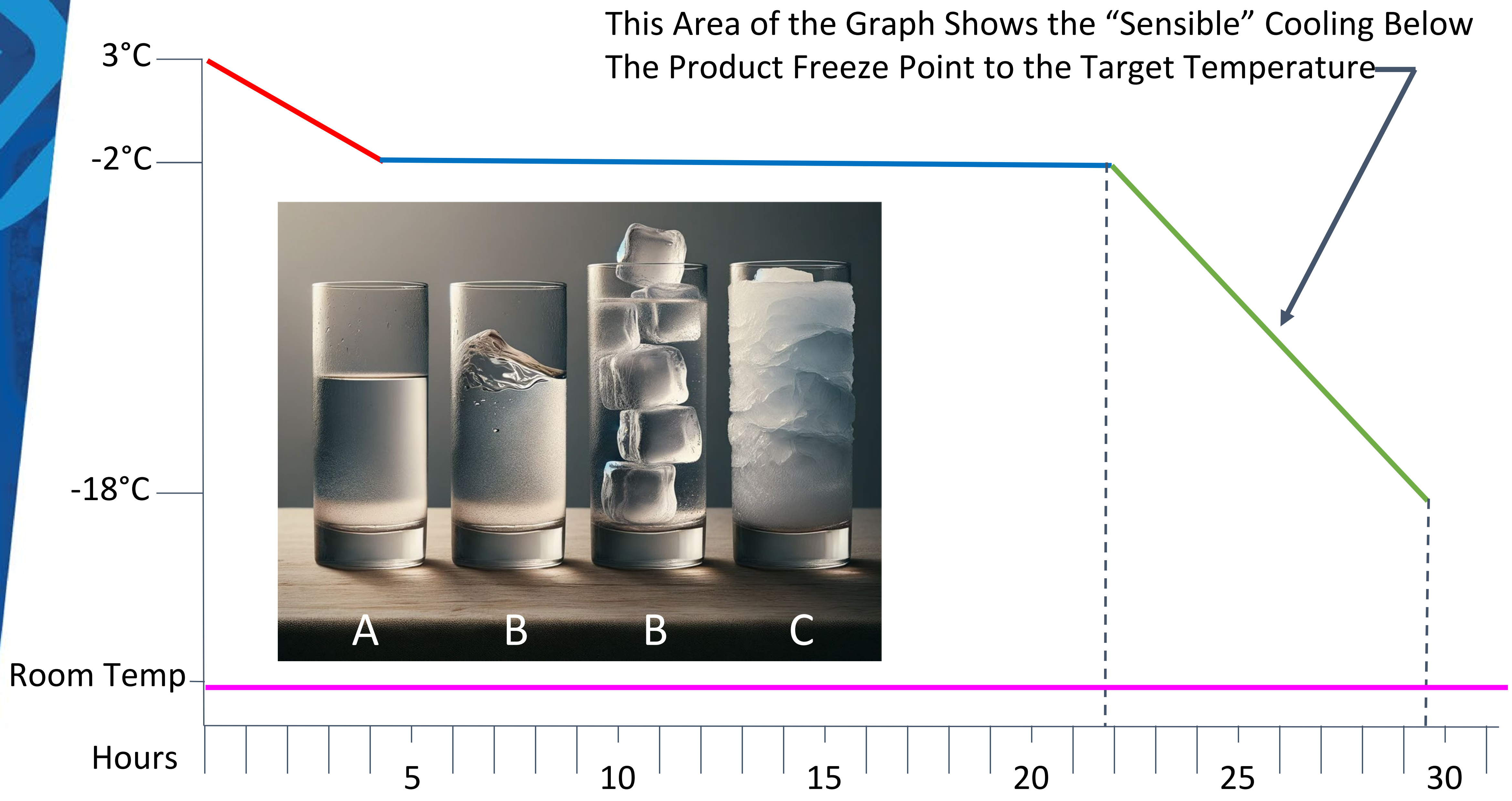
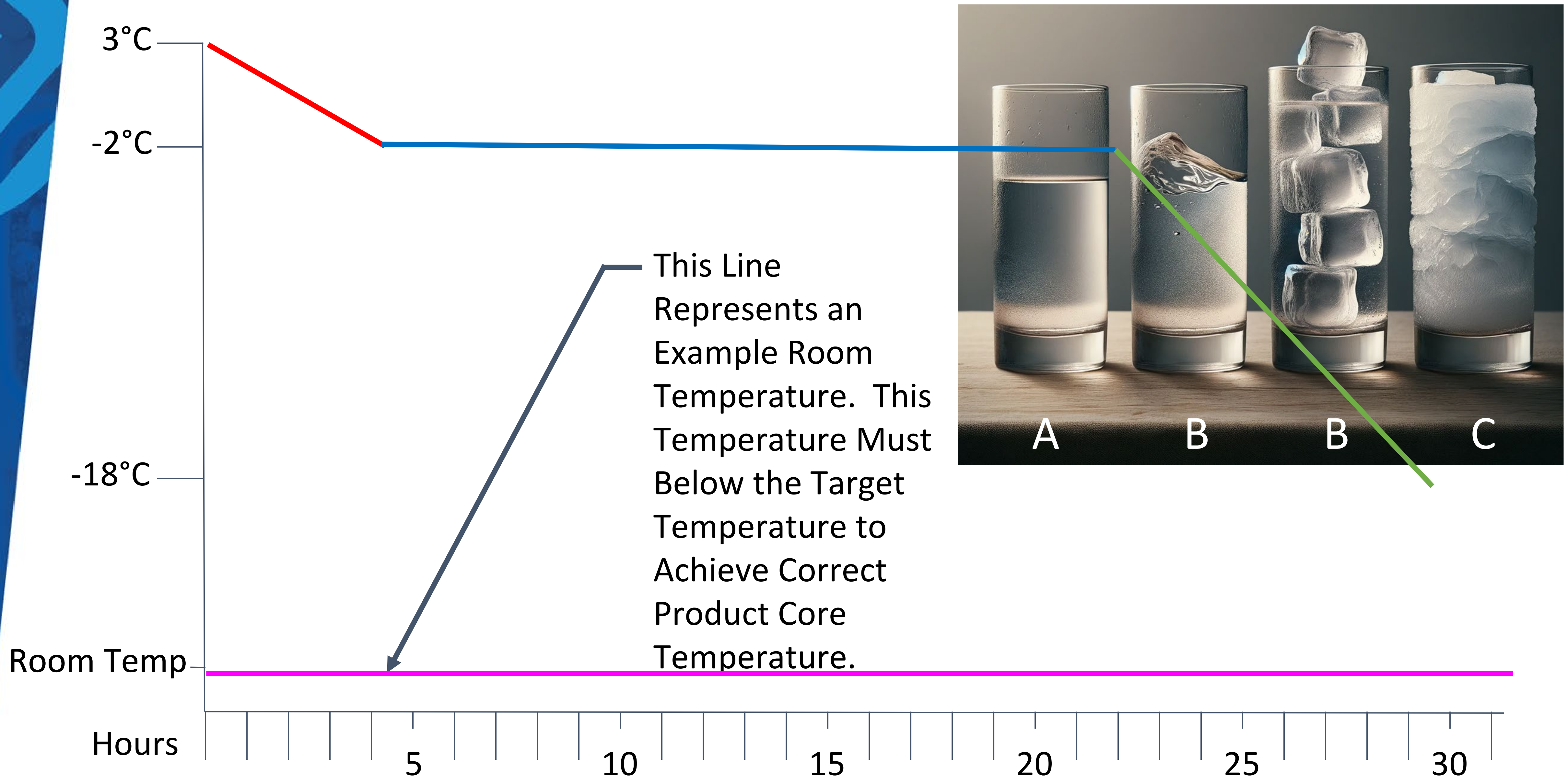
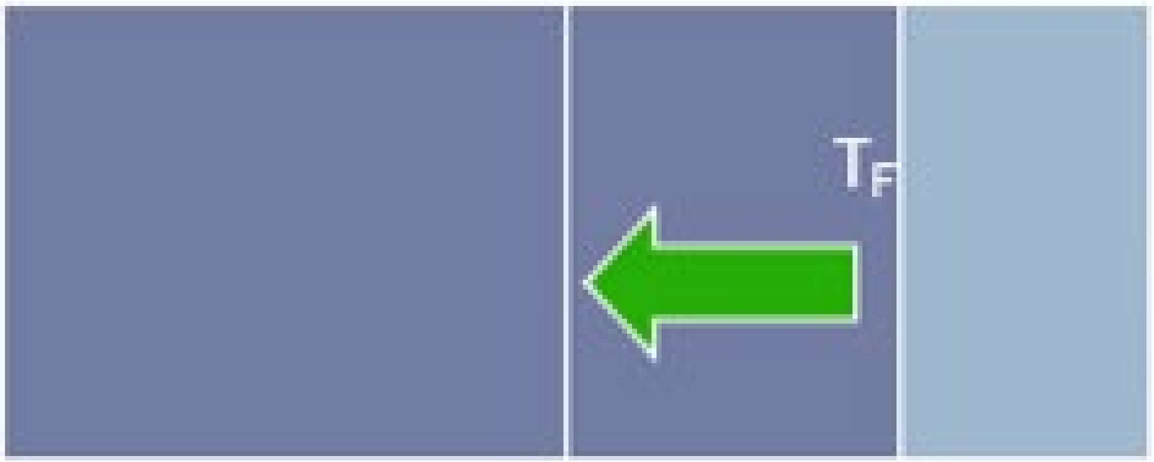


Typical Time/Temperature Freeze Graph



Time-To-Freeze

- Time to Freeze = time required to reduce geometric center of product from initial temperature to desired final temperature.

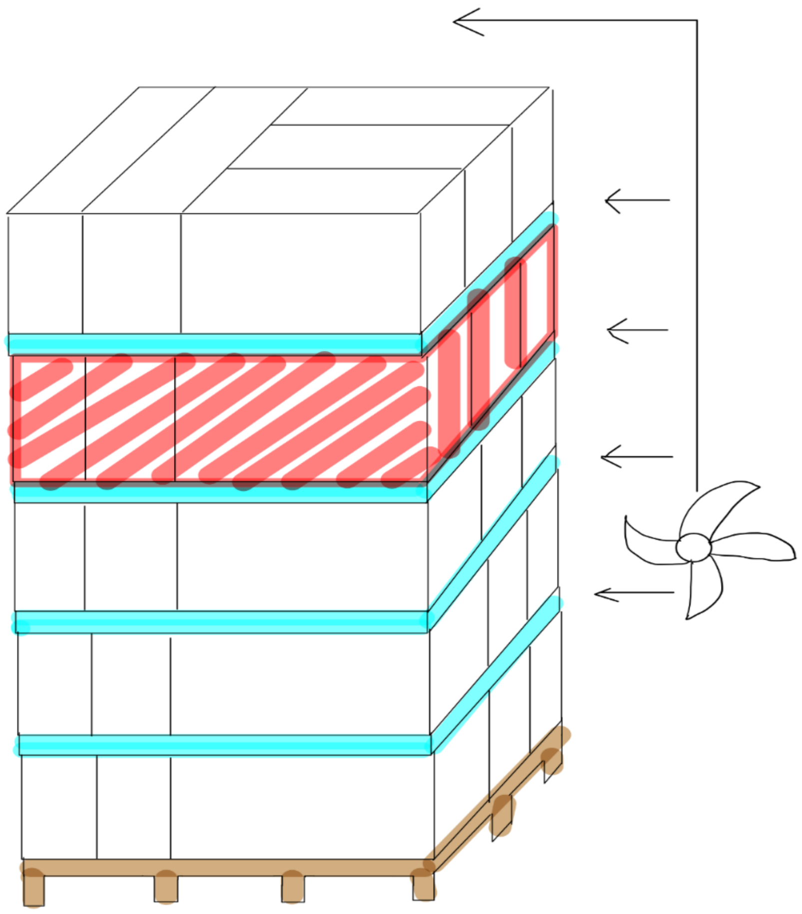


Time-to-freeze

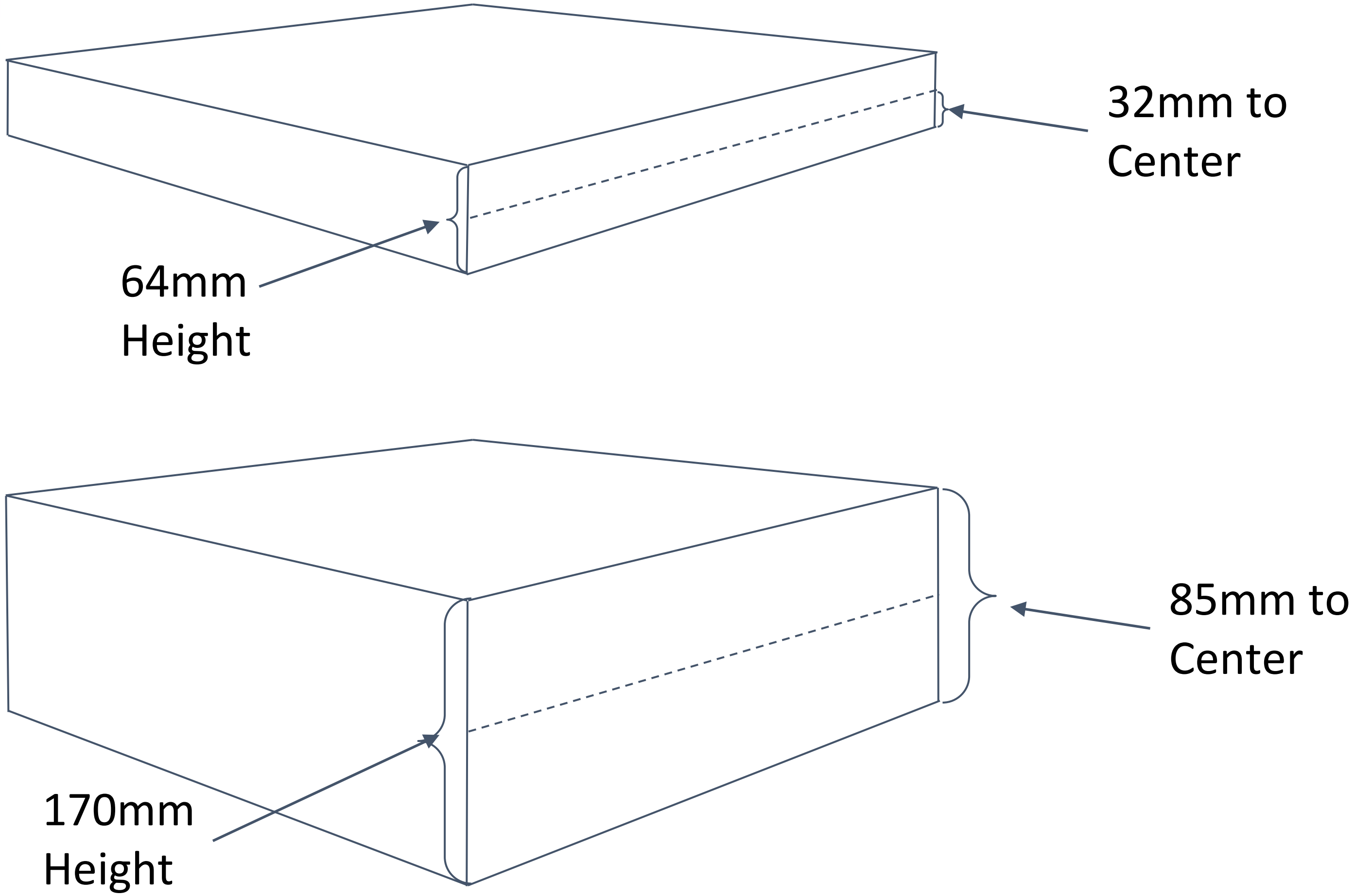
What affects time to freeze?

1. Product dimensions
2. Air Temperature
3. Type of Product (e.g. Chicken vs Vegetables)

Product Packages with spacers for blast cell

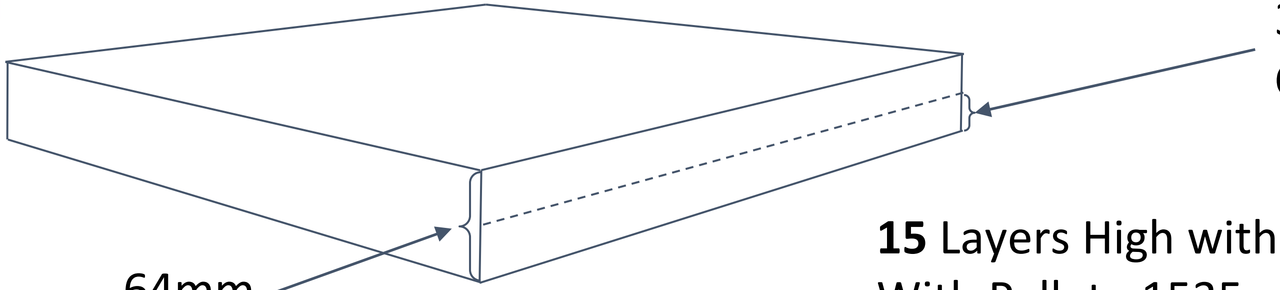


Case Height Consideration #1
Distance To Center

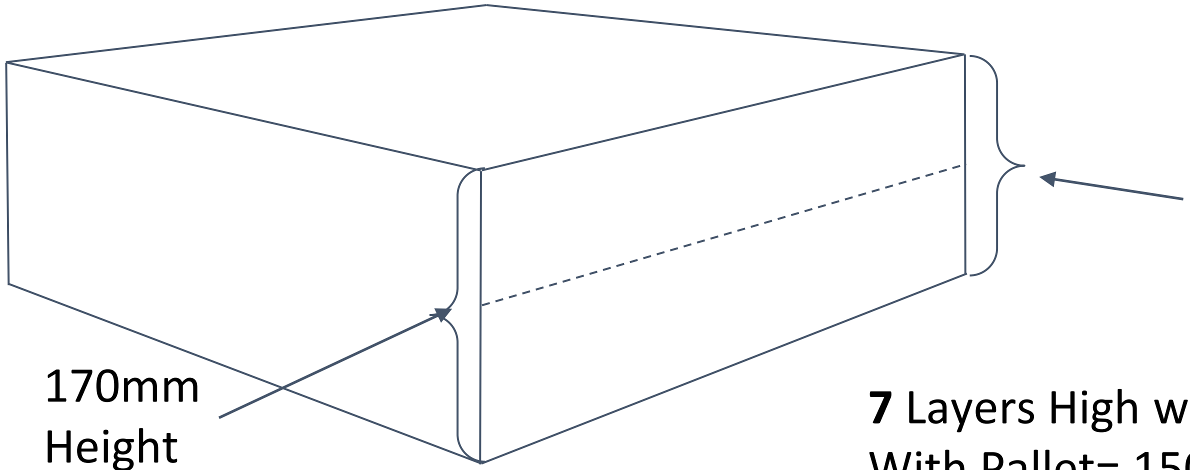


Taller Cases Drive Greater Distance to Center, Which Slows the Freezing at the Center of the Case.

Case Height Consideration #2
Spacers Per Stack

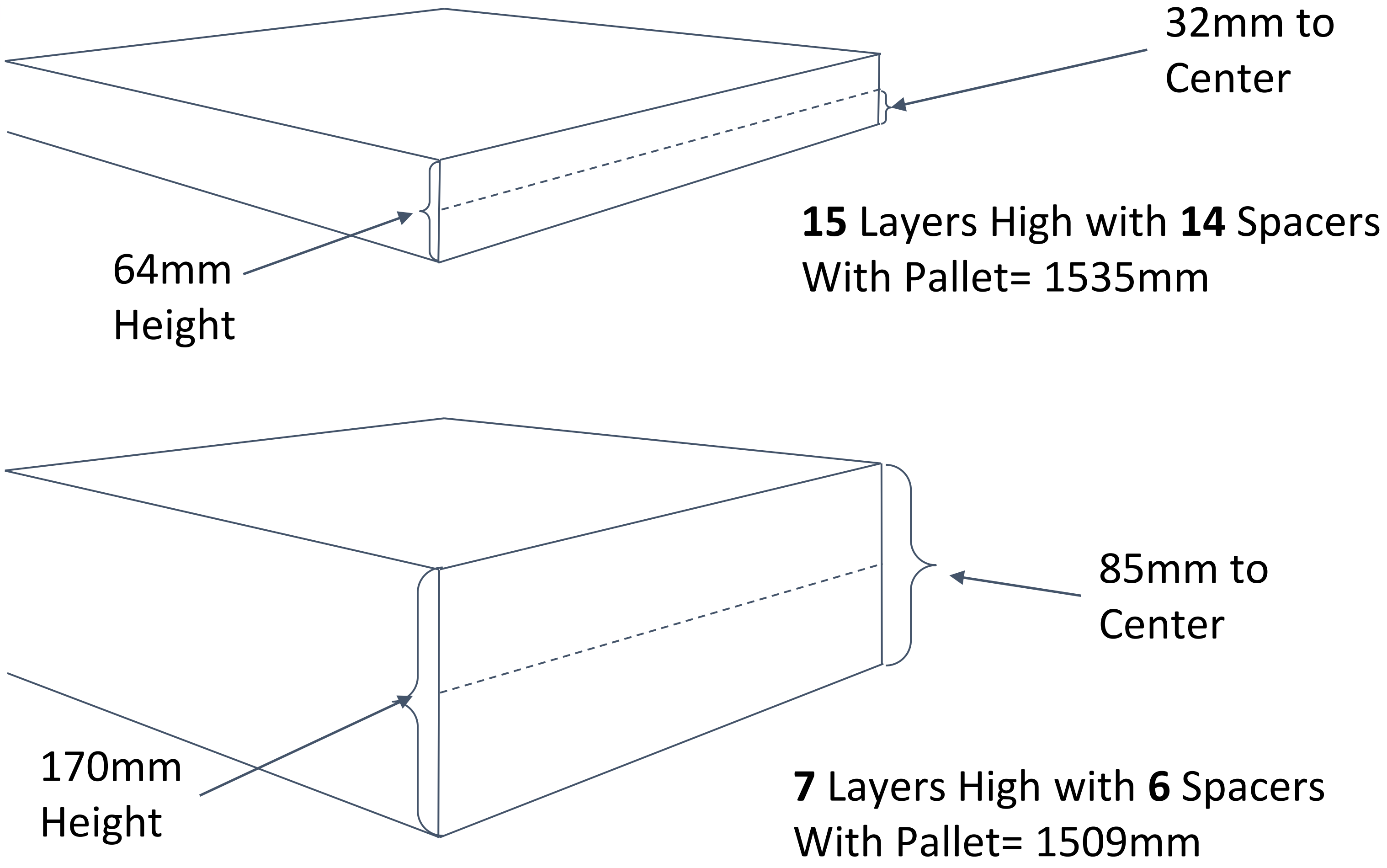


15 Layers High with **14** Spacers
With Pallet= 1535mm



7 Layers High with **6** Spacers
With Pallet= 1509mm

Case Height Consideration #2
Spacers Per Stack



Taller Cases Reduce the Number of Layers, Which In Turn Reduces the Number Spacers Utilized. Therefore the Number of Air-Flow Paths are Reduced.

Case Height Consideration #3
Combination of #1 and #2

- #1 Taller Cases Drive Greater Distance to Center, Which Slows the Freezing at the Center of the Case.

- #2 Taller Cases Reduce the Number of Layers, Which In Turn Reduces the Number Spacers Utilized. Therefore the Number of Air-Flow Paths are Reduced.

- #3 The Combination of These Factors Significantly Extend the Required Freeze Time for Taller Cases.

Convective Heat Transfer Coefficients

- The “h” value – a coefficient expressing the magnitude of heat transfer from the surface of the product to the cold medium.

Examples – Typical h-values	W/m² °K	BTU/hr ft² °F
Still Air	6-9	1-1.5
Air Blast (5 m/s)	25-30	4.5 – 5.3
Plate	100	17.5
Immersion (CO_2)	500	100
Cryogenic (liquid N_2)	1500	250

Blast-Cell applications

- In order to reduce the Time-to-Freeze for product packages on a pallet, spacers must be introduced to ensure that outside surfaces of packages are in contact with cold air.
- Air velocity (ft/min) must be maintained between package layers to ensure desired result.
- Air flow must be directed at upstream side of pallet; all cold air should move through spacers.

Spacer Crushing

The top 4 layers have good air passages. As the weight increases with each layer, the spacers are crushed and no air is able to pass through the pallet. Spacers should be replaced every 3-4 years.

Food Tempering Process

PART #2 -- Food Tempering Processes

- Definition = the addition of thermal energy required to change phase of ice within the frozen product, and increase the temperature of the product to a magnitude at or near the initial freezing temperature
- “Tempering” is the adjustment of a frozen food temperature from the normal storage temperature to some higher temperature, usually near and below the initial freezing temperature

Applications

- Why is “time-to-temper” important?

Warehouse operator may be asked by customer to adjust temperature of frozen food to higher temperature before delivery

Two considerations –

1. How much time is required?
2. What are important parameters?

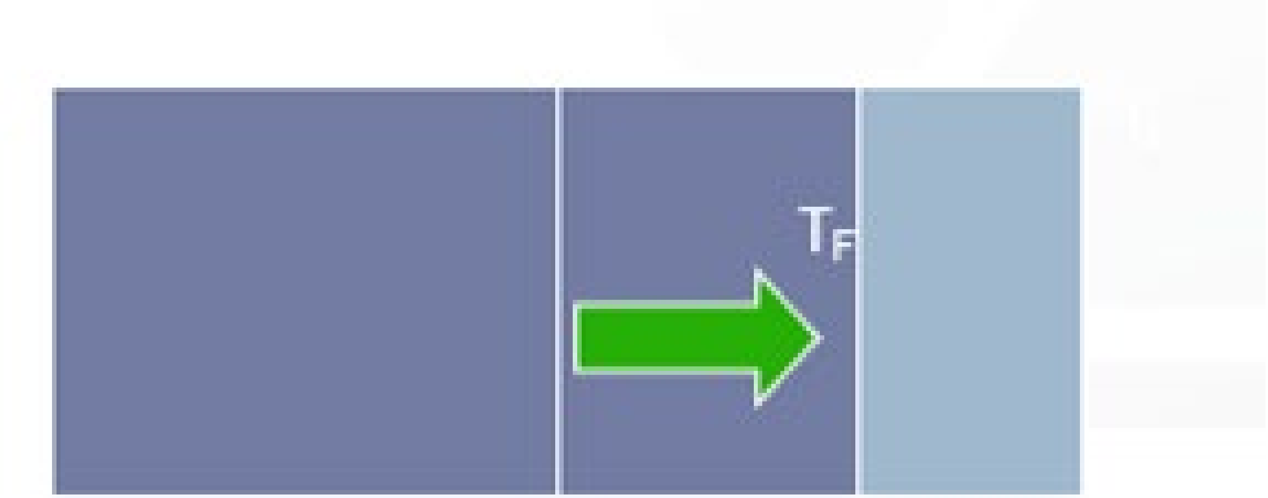
Frozen Food Properties during Tempering

- Changes occurring during process

1. Product solutes become more dilute as unfrozen water fraction increases during increase in temperature
2. The phase change from ice to liquid occurs over a range of temperatures
3. Temperature range is from typical storage temperature (-18 C; 0 F) to several degrees below initial freezing temperature

Time-to-Temper

Time-To-Temper = time required to increase mass average temperature of product from an initial magnitude to a desired final temperature.



Time-to-Temper

- Mass Average Temperature – the average temperature of a frozen product based on distribution of temperatures and mass of product
- Application is most obvious during tempering when significant differences in temperature occur between product surface and geometric center

Convective Heat Transfer Coefficients

- The "h" value – a coefficient expressing the magnitude of heat transfer from the surface of the product to the warm medium.

Examples – Typical h-values	W/m² °K	BTU/hr ft² °F
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Summary

- Temperature distribution history within food product during tempering can be predicted
- The impact of process parameters on tempering time can be evaluated
- The influence of product shape and size can be evaluated

Storage and Frozen Food Quality

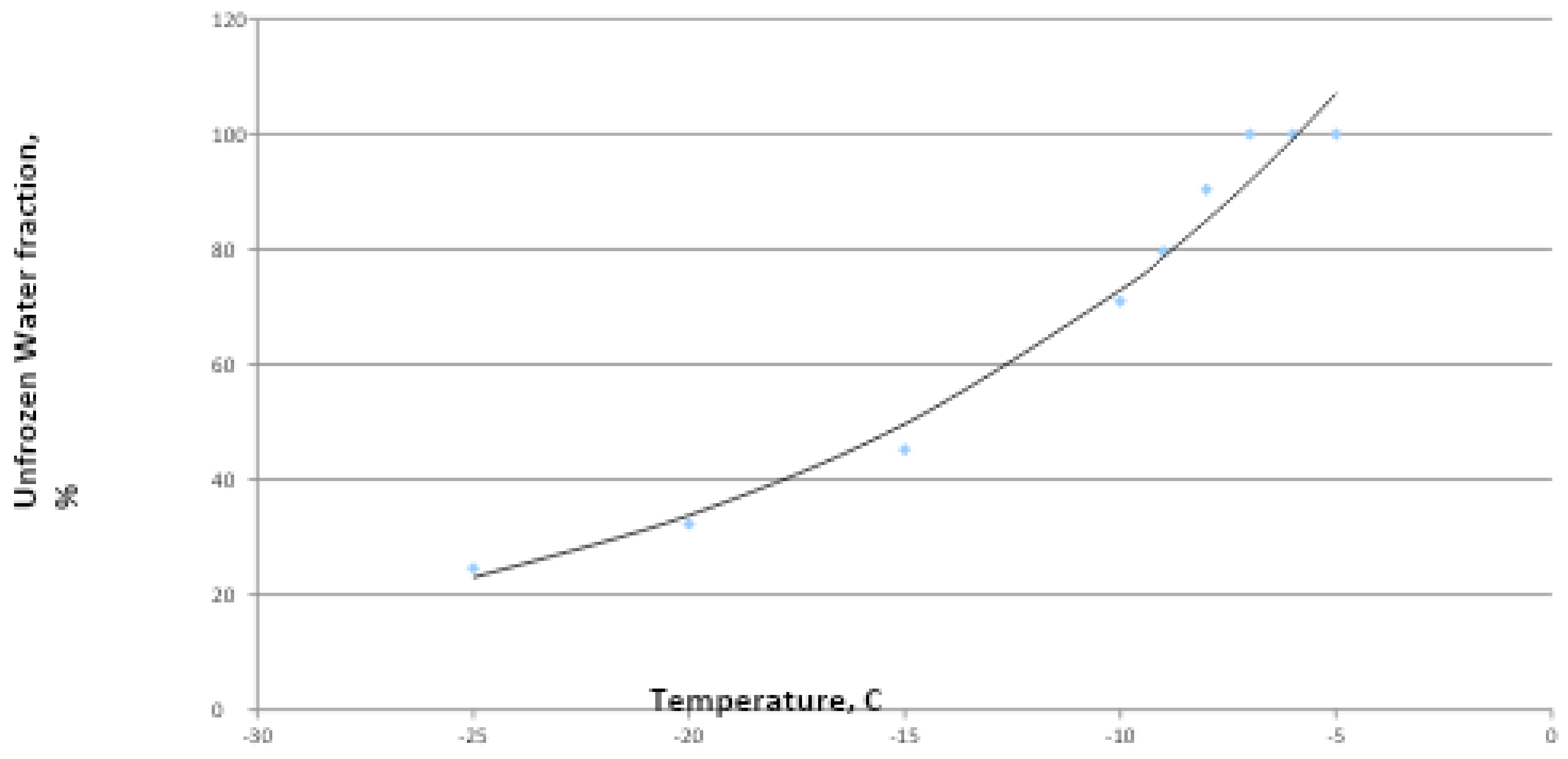
Part #4 -- Storage and Frozen Food Quality

- Significant literature has accumulated on the impact of storage temperature on frozen food quality.
- Based on USDA research from the 1950s, the optimum storage temperature of 0 F (-17.8 C) was established.
- The reductions in product shelf-life from storage at elevated temperatures, and from fluctuations in temperature, have been illustrated.

Frozen Food Quality

- Temperature elevations above optimum result in an increase in the percent water unfrozen; changes from 5% unfrozen to 15 % unfrozen.
- The availability of liquid phase water and elevated temperature accelerates deterioration reactions.
- When temperatures are reduced, rate of change is slow and large ice crystals are formed.

UWF vs. T for Beef



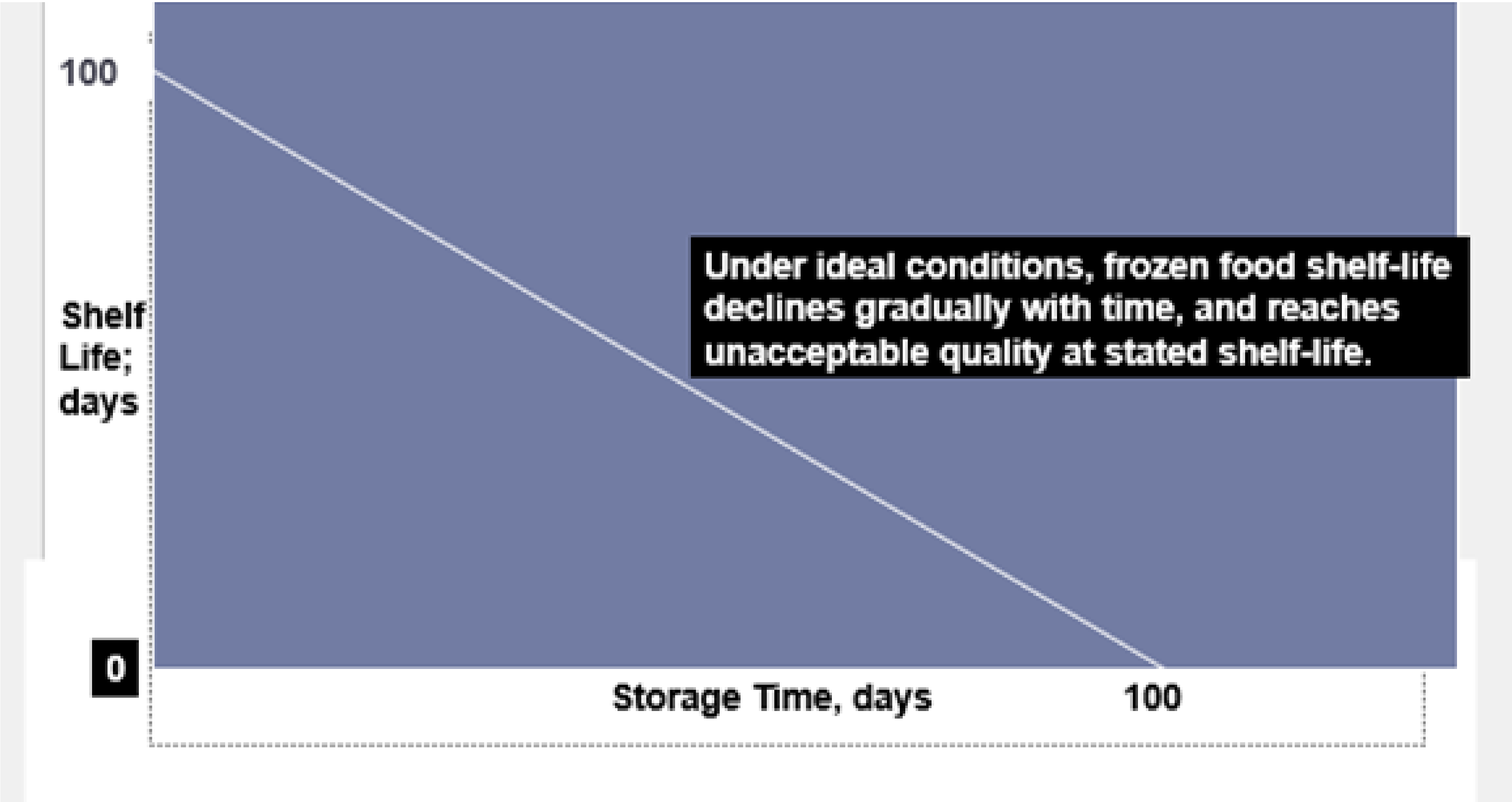
Storage Environment and Frozen Food Quality

- In general, the quality of a frozen food decreases with storage time.
- Shelf-life of frozen foods have been expressed as:

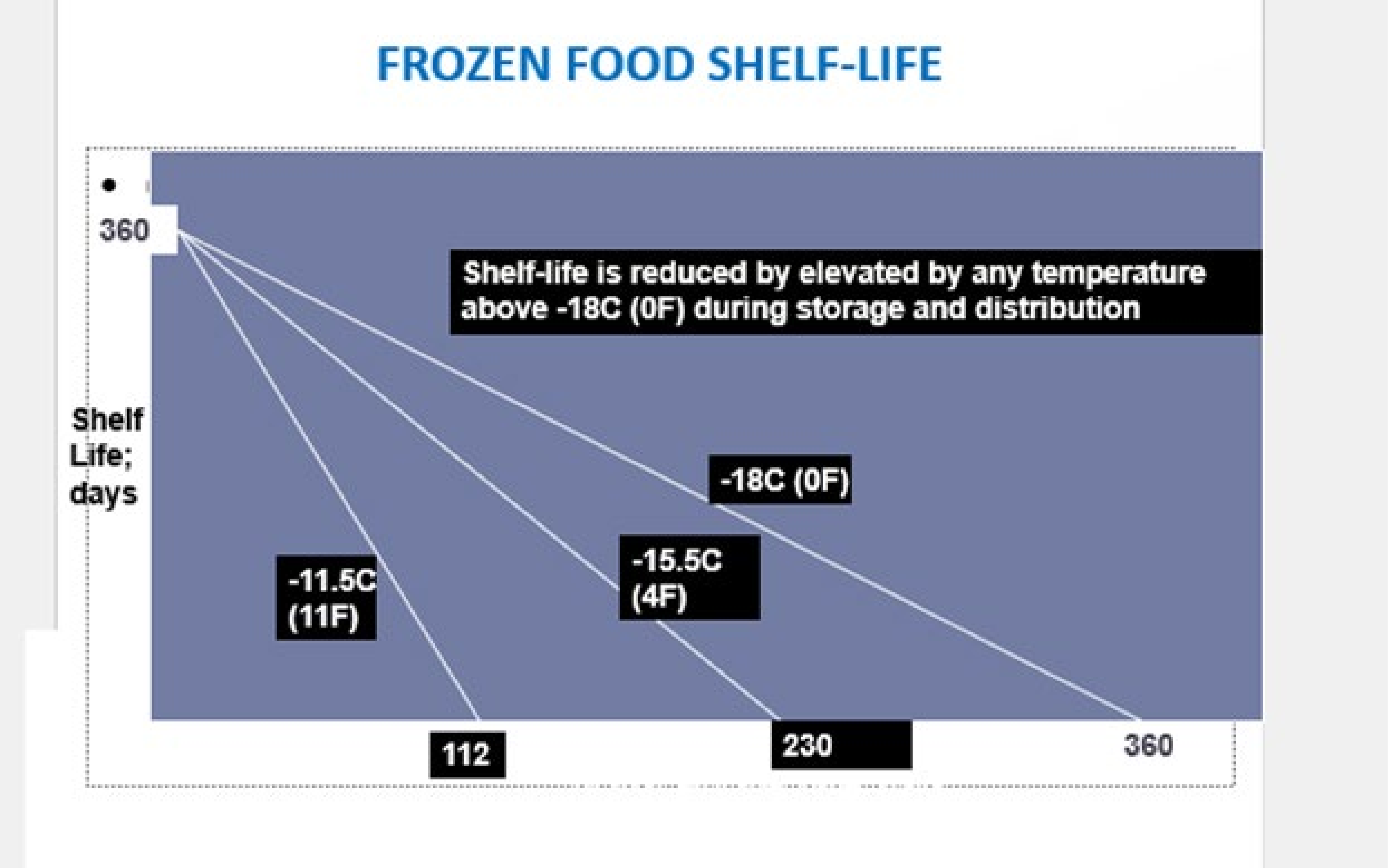
  PSL = storage time at constant temperature until change in quality is detected.

  HQL = storage time at constant temperature until a quality difference from a reference is observed.
- Most quantitative results are based on research conducted by USDA in 1950s.

Frozen Food Shelf-life



Frozen Food Shelf-life



Typical Frozen Food Storage Parameters

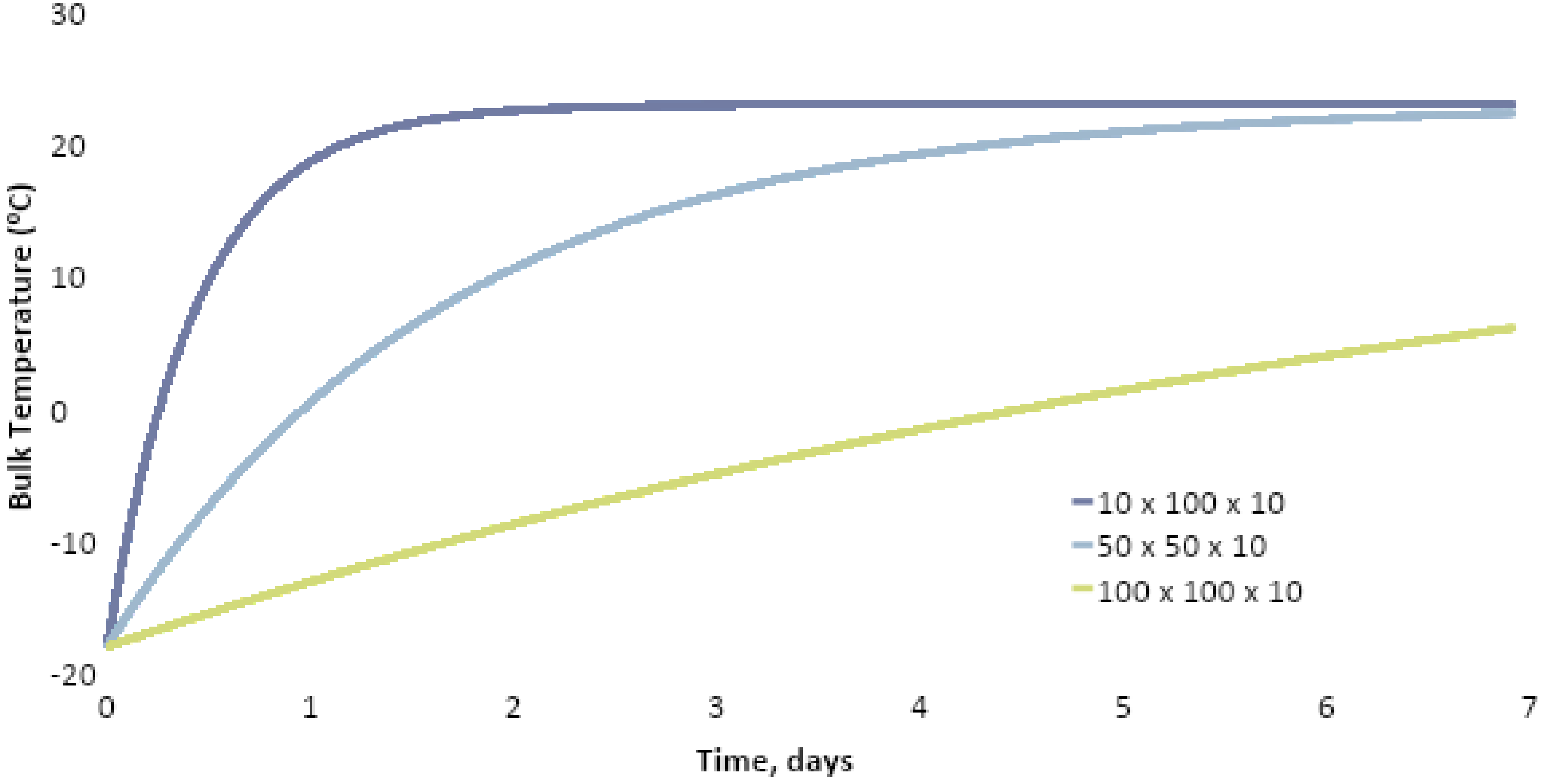
Food Category	Shelf Life	Sensitivity
Seafood	200	50
Vegetables	400	60
Fruits	350	63
Meats	215	65
Poultry	230	75
Ice Cream	300	100

Part #5 --Warehouse Air Temperature

Factors with influence on air temperature in the warehouse

1. Refrigeration system; on or off
2. Insulation of walls, ceiling and floor
3. Openings to air outside storage space
4. Total volume within warehouse
5. Amount of frozen product in warehouse

Air Temperature as Function of Warehouse Volume



Product Temperature

Factors influencing the product temperature when refrigeration system is not operating –

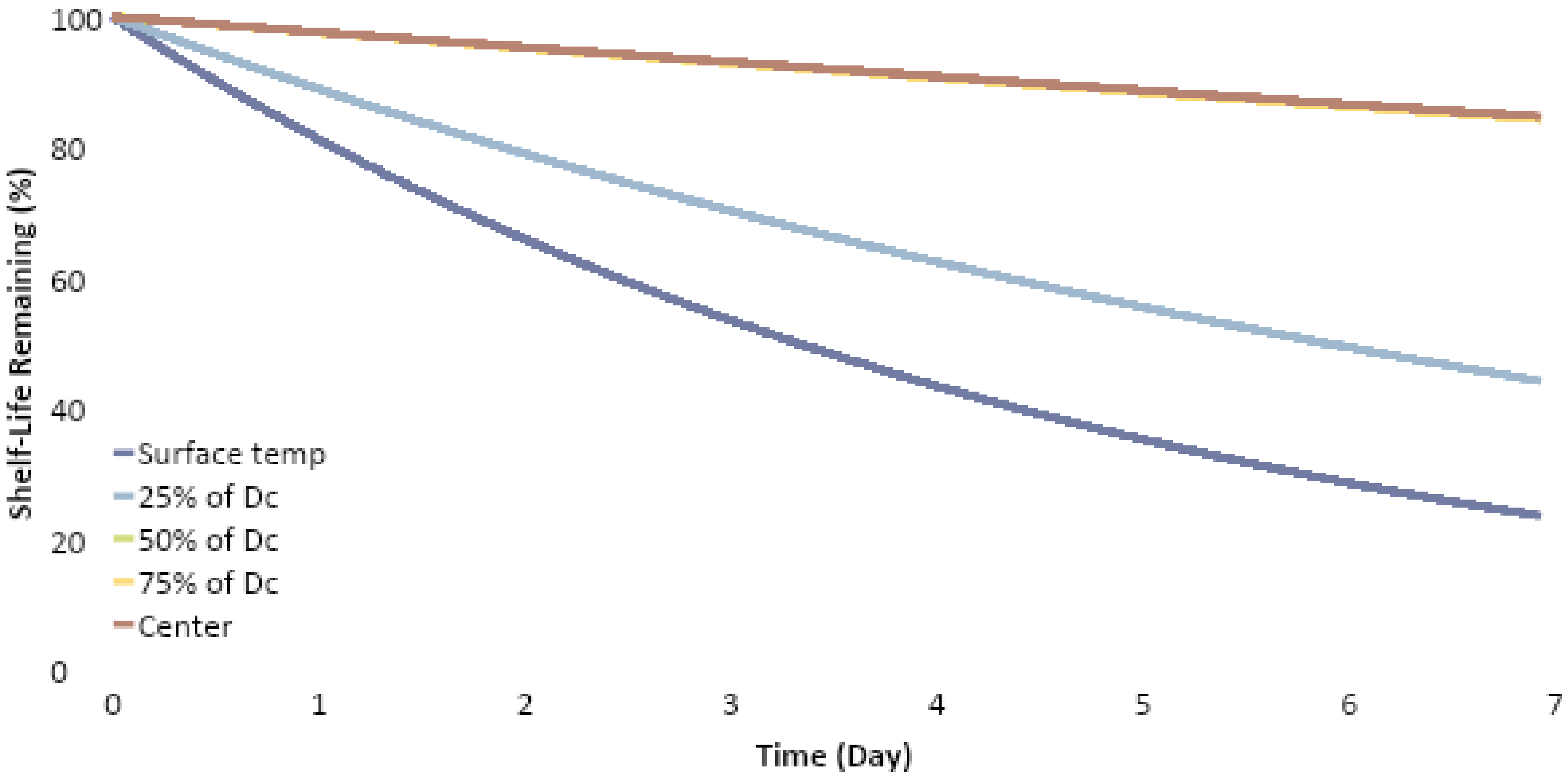
1. Difference in air temperature as compared to the product temperature
2. Air movement over product surfaces
3. Percent of space occupied by frozen product
4. Configuration of product in warehouse space
5. Product properties

Frozen Food Quality

The loss of frozen food shelf-life is accelerated by the following:

1. An increase in the product temperature
2. Location of product near an interface of warm air and frozen product
3. Configuration of frozen product stacking with more product surface area exposed to warm air
4. Frozen food quality attributes with greater sensitivity to changes in temperature

Frozen Food Shelf-life as Function of Location



Questions? Contact us!

- Robert Hernandez – rhernandez@uscold.com
- Bob Tippmann - btippmann@quickfreeze.com
- Amanda Brondy – abrondy@gcca.org
- Madison Jaco – mjaco@gcca.org

Thank you!

For more information, please visit www.gcca.org

This presentation is made in conjunction with the United States Department of Agriculture (USDA) Emerging Markets Program (EMP) and prepared by the Global Cold Chain Foundation (GCCF), formerly the World Food Logistics Organization (WFLO). The opinions expressed in this presentation do not necessarily reflect that of the U.S. Department of Agriculture or the U.S. Government.