BASELINE MONITORING OF KEY STORAGE AND DISTRIBUTION DATA IN THE FROZEN FOOD SUPPLY CHAIN

INDUSTRY GUIDANCE AND PROTOCOL

AMERICAN FROZEN FOOD INSTITUTE – GLOBAL COLD CHAIN ALLIANCE

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IMPORTANT NOTICE:

This guidance and information herein are intended to be a user-friendly resource to assist the broader frozen food industry. It has been developed to provide stakeholders with a single defined approach to recording time and temperature across the frozen food supply chain and its cold chain lanes. The clarity, practicality, and effectiveness of this protocol will be assessed during extensive trials in the U.S. and global frozen supply chain. It is anticipated that feedback from these trials may result in further amendments and improvements to this first edition document. Nonetheless, readers, practitioners, and companies are cautioned that this guidance does not provide fail-safe solutions for the processing, storage, distribution, and other logistics related to frozen foods, the supply chain, and the broader food industry. While the guidance endeavors to consider current industry practices, it is not intended to be a substitute for careful review or analysis of operational practices as it relates to each company's own products and operations; nor does adherence to this guidance ensure compliance with applicable statutory and regulatory requirements. **THIS DOCUMENT PROVIDES GENERAL INFORMATION AND GUIDANCE BUT IS NEITHER INTENDED AS NOR DOES IT CONSTITUTE LEGAL ADVICE.**

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1. Background:

The frozen food cold chain operates on longstanding monitoring and temperature recording policies. These policies have served the industry well, delivering high food quality and preservation standards. Around the world these policies have coalesced around broadly similar temperature bounds and are monitored and enforced through contractual and regulatory requirements that are checked at 'handoff' (or other) inspection intervals.

Since these common practices were established, significant innovations have been made in the equipment, buildings, and monitoring technology used to deliver the cold chain. Using these advances, most supply chain actors have greater access than ever before to data about the temperature journey of the frozen foods in their care. Yet, there is little shared understanding of how to map the temperature journey of goods beyond the interval recording compliance methods required in basic food safety protocols.

The American Frozen Food Institute (AFFI) and the Global Cold Chain Alliance (GCCA) convened a taskforce of industry stakeholders to establish an improved understanding and a common recognition of that temperature journey. Specifically, the taskforce objective was to develop a protocol which describes methods that the cold chain would employ to register/record the temperature fluctuations occurring in the journey of frozen foods from the producer to the final warehouse/distribution center. The broader purpose of such an exercise would be to utilize collected data as a baseline for further studies and research on the impact of temperature fluctuations on frozen food products.

In the journey of frozen foods from the point of freezing to consumption, the product temperature fluctuations that occur across the logistics chain are important yet not well understood considerations. Notwithstanding the gaps in knowledge, keen observation of time and temperature exposure of frozen foods is likely to reveal:

- Variations in the set point used for different frozen food products
- Variations in set points applied by different operators in the same logistics chain for the same product
- Significant deviations from the temperature set points during a product's journey

Each of these factors has important ramifications for the energy consumed in the flow of frozen foods as well as potential food safety, quality, and shelf-life implications. The first step of improving our ability to reduce energy consumption and thus greenhouse gas emissions across the frozen food chain, whilst respecting food safety and maintaining product quality, is to learn more about existing temperatures (air and product) across various categories and the inherent variability of disparate lanes in the industry.

Subsequent and concurrent to this work, the task force will pursue standard protocol development in additional areas, including food quality and shelf-life assessment,

food safety considerations, and energy measurement and reporting. These efforts aim to generate guidance documents for industry to follow as the frozen food community undertakes monitoring and assessment studies at large.

2. Scope and Objectives:

The purpose of this paper is to provide an industry recognized approach to data collection that can lead to an improved understanding of the key extrinsic (factors pertaining to the food storage environment, specifically time, temperature and relative humidity, which influence the food's shelf life) parameters as they currently occur in the frozen food chain.

Our objective is to understand and evaluate the extremes of what is happening in a pallet (i.e., at the most stable and at the most critical point in a pallet) and the consequence of the pallet being placed in a certain location (e.g., inside a truck, reefer container or cold store/warehouse) where there are known hot spots and cold spots.

Preference should be given to acquiring high-quality data which can be understood (i.e., data from pallets where the location and temperature as a function of time for the entire supply chain can be tracked) and where there is certainty that the measured pallets remained intact as an entire unit.

Upon completion of data collection on what is happening, this research will consolidate/combine data from numerous sources/supply chains so that an understanding of sector-wide performance can be assessed. This aggregation is important for defining sector capability and facilitating the identification of standard practices for cold chain operation. The success of initiatives to warm the supply chain, which in turn could reduce both energy use and GHG emissions may depend on the implementation of certain practices throughout the sector.

This protocol can be used to guide a baseline time-temperature monitoring study of a specified frozen food supply chain. We identify which attributes should be recorded, what parameters should be measured, where to place the measuring devices and a basic design of a supply chain mapping exercise. The protocol includes a few useful practical tips ensuring efficient data acquisition and data processing. We make a distinction between an optimal, a standard, and a bare minimum study.

The protocol has been designed to measure the temperature in the cold chain from the point at which the product is packed in final containers or palletized until it reaches the customer's warehouse. Whilst recording of product temperature post freezing and at point of first transition is recommended, the initial freezing of the food and any subsequent storage of the frozen product prior to final packing and/or palletization are not covered in this protocol as these activities are in the control of the processor prior to product entering the supply chain. The transport, storage and preparation of goods once they leave the final warehouse/distribution center of the customer are also not covered in this protocol due to challenges associated with

monitoring the de-palletized components as they occur for display and sale in retail freezer cabinets and purchased individual packages taking different 'last mile' journeys and subsequent freezer storage in consumers' homes. See Table 2. Supply Chain Actors for details.

The product quality and acceptable shelf-life of a frozen food is primarily determined by the time-temperature conditions that the product is exposed to from the point of freezing to the point of consumption (including steps involved in preparing not-ready-to-eat frozen products for safe consumption). It is imperative therefore that the entire frozen storage life of the product is considered, and that the time-temperature monitoring of periods not covered by this protocol are also captured by monitoring studies tailored to the specific situation.

3. PART 1 – Design of the study

Purpose: To ensure that the study is set up to capture all the relevant contextual and data parameters to make the data consistent and comparable to other studies.

Supply chain Mapping:

- Identify and develop a basic supply chain network map (from production facility to retail/food service/distribution center) with the key target temperatures in each unit operation and the duration in each of those
    - Warehouse
    - Mode of transport (road, rail, ship, air)
    - Equipment (including cold air delivery system from top or bottom)
- List the various supply chain actors, either by name with their permission or anonymized (this could be just one company in a closed chain, or a sequence of companies handling different parts of the product journey)

Food and Packaging Characteristics:

- Frozen food product:
    - Type of freezing method (e.g., bulk freezing, IQF, flash freezing, spiral freezing, etc.) and product temperature immediately after freezing, providing a line of sight to the initial freezing quality (this would be product dependent, however, infra-red temperature sensors to measure product surface temperature may be adequate)
    - Detailed description of the frozen food (i.e., type of food; cut or whole; proximate nutritional profile; cooked or raw; cooking or preparation instructions; other food safety or quality information provided on the label)
    - Frozen food product temperature at the time of transition from the first node (this is typically in the same facility where freezing occurred before destined to a frozen storage warehouse in the same facility or a different facility). At this first node, frozen product is typically

palletized for further storage or transport. If product is not in final packaging (palletized) at first node transition, again, temperature recording would be performed using industry standard methods e.g. probes/infrared scanners
    - Take photos for visual documentation

- Packaging – individual product, case, pallet:
    - If the product is individually wrapped, the packaged individual product unit (amount, size, headspace in packaging, etc.)
    - Packaging material of the individually wrapped unit (mentioning type and permeability of packaging – Oxygen and Moisture (Water) Vapor Transmission Rate specifications for barrier packaging which determine the shelf life of food packaging[1]
    - If the frozen product is packaged in bulk (i.e., a tote or other container) or retail (e.g., 40 lbs. of IQF peas would be packaged in a bag in a box format)
    - If there is secondary packaging (e.g., 40 x 400 g packages placed in a case such as a bag in a box) material and dimensions
    - Dimensions of the case and the pallet, number of cases in the pallet, amount of product in each case, space between pallets - if any - when complete pallets are loaded in a container
    - Take photos for visual documentation

Preparation of Measurement Devices:

- Clearly label each sensor with a unique identifier and its placement location
- Label each pack containing a sensor
- Label the pallet(s) equipped with sensors
- Take photos for visual documentation to verify the exact position and appearance of the sensors
- Record locations of each sensor and the time activated

Measurement Parameters for Inclusion:

- **Set point temperature** of node in the supply chain = temperature set by the operator of the facility. Set points are likely to change depending on the location of the product within the supply chain. Set points are targets, not actual measurements recorded by a sensor, so a protocol for the operator to report must be provided.

- **Ambient temperature** at point of product transfer = temperature outside the facility used to store/transport the product**.** A temperature sensor is not needed; just a mechanism for recovering the information.

[1] https://www.ansi.org

- **Facility air temperature** = temperature in proximity to product. This value requires a sensor, but the temperatures will depend on the location of the sensor within the facility, and the facility holding the product at any point (warehouse, transport, loading dock, etc.) within the supply chain. These are likely to be the most valuable data to be collected.

- **Frozen food product temperature** and its distribution within the product package; measured by three sensor placements on a pallet. The distribution of temperatures within a pallet will depend on volume of product on pallet, packing arrangement, space between packages, shrink-wrap, etc. Finally, it is important to note that there is always a risk for a package with a sensor to be moved to a different location on the same pallet or to a different pallet.

- **Relative humidity** of the storage location, i.e., warehouse, room, reefer container (preferred but not required)

- **Geo-location** (longitude/latitude) as product is stored and moved across the chain

The emphasis of the study should be on collection of the deviations in product temperatures. The frequency of data collection should ensure that the duration and magnitude of the product temperature deviations are recorded and therefore we must capture de-frost cycles and be able to capture breakdowns or power disruptions, as well as the location of the deviation in the supply chain.

4. PART 2 – Monitoring and Conducting the Research

Purpose: To provide guidance on how to undertake the study or pilot with an aim to ensure greater comparability of results between studies across varied supply chains.

Placement of Sensors in/on the Pallet:

Sensors should be placed during the first palletizing of the product.

For minimal sensor placement, one sensor should be placed in the center of the pallet (red circle in Fig. 1). A standard setup involves three sensors: one in the center (red circle), one at the bottom corner (black circle), and one at the top corner (black circle), placed diagonally. Optimal placement uses nine sensors: one in the center and one in each corner of the pallet.

Sensors may be placed inside product cases if they are individually wrapped product units in the case/box and can be added inside the cases without compromising safety and quality of the frozen product or if products are specifically used for the study and not for human consumption. Direct contact of the sensors with exposed food products is prohibited (unless the research design is specifically for temperature tracking in foods and foods are labeled as not for human consumption). Take photos for visual documentation to verify the exact position and appearance of the sensors.

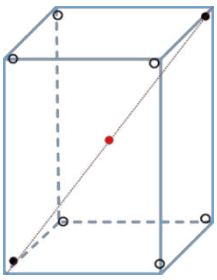

Fig 1: Sensor placement in pallet (red basic, red + black standard, red + black + open circle optimal)

Placement of Pallets Equipped with Measuring Devices in Transport Equipment:

For a minimal study, use one pallet equipped with sensors in the second-to-last row from the door end (red pallet in Fig. 2). The standard study complements the basic study with an additional pallet with sensors in the first row from the unit end (black pallet Fig. 2). The optimal study complements the standard study with an additional pallet in the center row (brown pallet Fig. 2).

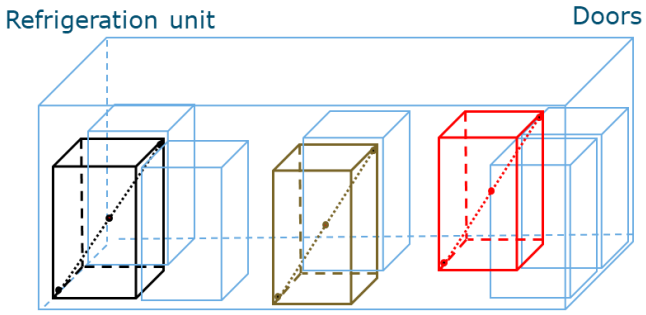

Fig 2: Pallet placement in transport equipment (basic red, standard red + black, optimal red + black + brown)

Design of the Product Supply Chain Mapping Exercise:

- Minimum requirements
  - Data should ideally be monitored in at least two different product supply chain routes. For each route an absolute minimum of three separate time and temperature monitoring trials are required with three different data collection time periods, preferably with trials during different seasons of a year and/or traversing different geographic regions

  - The measurement interval should have a frequency capable of capturing foreseen temperature variations

  - Ensure sensors measure within the expected measuring range and periodicity

- Design should be capable of capturing events (door open/close events, loading/unloading times)

Tools and Sensors:

Real time data loggers include:

- Temptales (https://www.sensitech.com/en/products/monitors/conventional/)
- Logtags (https://logtagrecorders.com/)
- Escorts (https://www.escort-instruments.ch/products/index.htm)
- Tive (https://www.tive.com/?r=0)
- Berlinger (https://www.berlinger.com/shipment-monitoring-solutions/last-mile-temperature-indicator)

The products mentioned above are neither endorsed nor guaranteed by this protocol or by AFFI or GCCA

5. PART 3 – Data Collection and Organization

Purpose: To ensure that the data gathered meets the minimum requirements for a study of this nature and makes it possible for data from disparate studies to be compared if the participant(s) (company or companies) is willing to do so.

Minimum Data Requirements:

- Data should be logged in real-time at hourly or shorter intervals*. However, it can be polled from passive devices at the end of a journey; it does not have to be relayed in real time to a central hub

  **"Frequency" should depend on the sensing system, but the assembly of information from any given sensor at the conclusion of a trial should be sufficient for these trials. Note that the measurement intervals could be modified to meet the needs of the study, providing measurement intervals ensure that data is also collected hourly as a minimum.*

- When using multiple sensors ensure all sensors log with the same time interval

- Date and time of each measurement
  - Synchronize time settings using a universal time standard, such as Coordinated Universal Time (UTC), to avoid confusion

  - Ensure all stakeholders are aware of time zone differences and convert times accordingly

- When using multiple sensors, identify any offsets by keeping all sensors in the same temperature environment while measuring. Note this as an event

- Data should be in a downloadable format and exportable to spreadsheets

- Sensor ID: Unique identifier for each sensor

- Placement: Exact position within the load (top layer of pallet, middle of truck, location in warehouse)

- Geo-location of each measurement. The critical connection is between the location (and time) and the temperature value

- Incomplete datasets or data that cannot be confirmed as both complete and unadulterated should not be included in data collection exercises where the intention is to map time and temperature across the frozen food supply chain*.

  **An incomplete dataset is one that does not monitor the time and product temperature from the defined start point to the defined end point, and/or does not capture all temperature impacting activities such as defrost cycles, power-off events, loading/unloading. Adulterated datasets may occur by accident such as technical failures, or by intention, such as when a recording or the transmission of a temperature is scheduled to avoid coinciding with a defrost cycle, a power-off event, loading/unloading, etc.*

Organizing Data from Different Parts of the Supply Chain:

As set out in part 1, it is important to map out the stages involved in the supply chain journey from the processor to retail distribution location. This section illustrates how to build a nomenclature to ensure that the data gathered for each supply chain stage are captured consistently.

Supply Chain Map Nomenclature:

This example model would ensure that the various stages of the supply chain are separately identified and be flexible enough to account for variations in supply chain lanes.

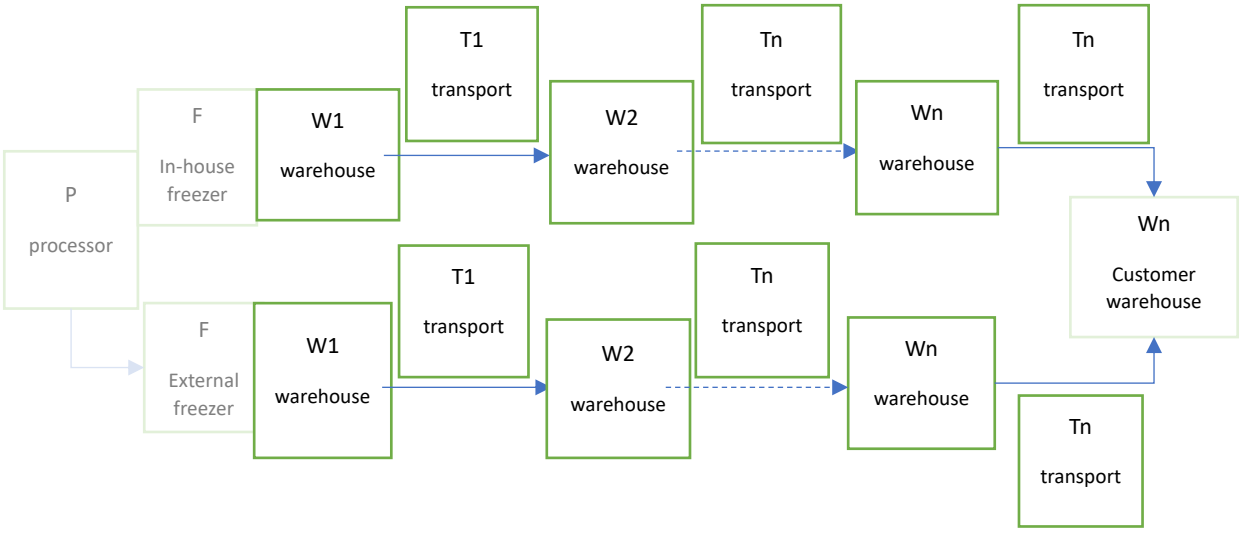

Figure 3. Supply Chain Nomenclature

The steps in the supply chain considered out of scope for measurement are shown in lighter colors, while the steps in darker colors are within scope. The intention is to measure the temperature in the cold chain from when the product is packed in final containers or palletized until it reaches the warehouse of the 'customer' (non-participant in this project). The diagram is further elaborated in Table 1 - Supply Chain Actors.

Supply Chain Actors:

Code	Definition	types	In scope	subtype	Notes / Data
P	Processor – the food producer		No		
F	Freezer	In house	No		**Identified as 'first node' in document**
		External	No		
W	Warehouse (frozen storage, cold store)	First storage of frozen product	Yes	Different dock designs (or not)	• Set point temperature of node in the supply chain • Ambient temperature at point of product transfer • Relative humidity of the storage location, i.e., warehouse, room, reefer container (preferred but not required) • Geo-location (longitude/latitude) of product as stored and moved across the chain
		Supply chain	Yes		
		Manufacturing, Retail or Food Service customer	No	Different dock designs (or not)	• Ambient temperature at point of product transfer • Measurement may stop after the product enters the warehouse at these locations (manufacturer, retail, or food service)
T	Transport	Truck	Yes	Air delivery system, other specifications	• Ambient temperature at point of product transfer • Geo-location (longitude/latitude) of product as stored and moved across the chain
		Rail	Yes		
		Sea	Yes	Container specification	
			Yes	Pallet in hold	
		Air	No		

Table 1. Supply Chain Actors

For each F, W, T actor:

- Geo-location (longitude/latitude) as product is stored and moved across the chain
- Within-facility location (e.g. storage location)
- Temperature of that storage location, according to data collected by that actor for the time that the product was resident.

Thus, a temperature logger data set contains at least one, and maybe more than one journey between nodes W1 and Wn using T1 to Tn. Each Wn to Wn+1 pair is a segment of the journey.

Data Dissemination:

The frequency distribution of deviations from setpoint will describe the temperature performance of each W and T subtype for stable operation, and for transitions (commencement, termination) (in each direction) between combinations of W and T subtypes.

Annex 1.

The GCCA Cold Chain – Transportation Best Practices guide provides current safe food transportation best practices, identifies common causes for temperature fluctuations and suggests actions to help minimize deviations to the set point temperature.

Appendix, 13.1 Airflow Considerations on Page 36, highlights several causes for poor air circulation which can lead to temperature management problems.

Organizations:

About the American Frozen Food Institute (AFFI), The American Frozen Food Institute is the national trade association promoting and representing the interests of all segments of the frozen food industry. With over 400 frozen processors and associate members, AFFI works to advance the industry's priorities, elevating the voice of frozen, and driving solutions for category performance. More information at www.affi.org.

About the Global Cold Chain Alliance (GCCA), The Global Cold Chain Alliance represents all major industries engaged in temperature-controlled logistics and is dedicated to building a universally strong cold chain where perishable products maintain quality and safety through each link. GCCA serves as the focused voice of the cold chain industry, representing 1,300 member companies in over 85 countries. More information at www.gcca.org.

About the International Frozen Food Network (IFFN), The International Frozen Food Network is a collective of the world's leading frozen food associations. The aim of IFFN is to raise awareness of the benefits of frozen foods and share best practices within the international frozen food industry. The network focuses on food safety, communication, and sustainability. The supporting organizations within IFFN are:

- American Frozen Food Institute (AFFI), United States
- British Frozen Food Federation (BFFF), United Kingdom
- Global Cold Chain Alliance (GCCA), United States
- Die Lebensmittelindustrie, Austria
- Deutsches Tiefkühlinstitut (*dti*), Germany
- Unione Nazionale Alimenti Surgelati (UNAS), Italy
- VriesVers Platform, Netherlands

About the "The Move to -15°C" Coalition: "The Move to -15°C" Coalition is a sustainability initiative dedicated to cutting carbon emissions in the frozen food supply chain. The cross-industry collaboration is building the evidence base to support a transition of the standard temperature set point of the cold chain to -15°C which would cut greenhouse gas emissions and lower supply chain costs. More information at https://www.movetominus15.com/


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