Report: Study of Thermal Protection for Mango Pallets During Mixed Load Shipments

Prepared for: National Mango Board

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Abstract

Delivering mangoes with the highest possible quality requires optimal temperature control during the entire distribution process. The optimal transit temperature for mangos is around 55°F (12.8°C). Typically, mangos are delivered to retail stores in mixed load refrigerated trailers, which contain a wide variety of food items. The trailer's set temperature is based on a compromise among the products being transported and is generally dictated by the food products that require the lowest temperature, which is around 36°F (2.2°C). Many retailers will not accept mango shipments that have a pulp temperature below 48°F (8.9°C). Pallets of mangos that are shipped without a pallet cover do not have enough thermal protection for standard transit times of 2 – 3 days.

Objectives

The main objective of this study is to provide the National Mango Board with a comprehensive study of commercially available pallet covers used for the thermal protection of mango pallets that are transported in a mixed load refrigerated trailer. To meet the main objective, sub-objectives must be met in order to understand how various pallet covers can thermally protect the load as well as determine critical areas in a pallet that can be responsible for temperature excursions.

This project studied the thermal protection level of mango pallets that utilize four commercially available pallet covers. The pallet covers were tested with and without a base. The pallet covers were tested in an environmental temperature chamber set at 2.2°C (36°F). Temperature recordings occurred at 23 locations throughout each pallet in order to provide a full temperature distribution profile. Mango pulp temperatures were measured in order to gain a realistic idea of the mangos actual temperature since air temperature can vary by several degrees. The air temperature and relative humidity under the pallet covers were measured.

Sub-Objective 1: Measure the level of temperature distribution throughout a pallet without any thermal protection in order to provide a basis of comparison. The uncovered mango pallet was exposed to a constant temperature of 2.2°C (36°F).

Sub-Objective 2: Measure the level of temperature distribution and thermal protection of four commercially available pallet covers without base protection. The covered mango pallets were exposed at a constant temperature of 2.2°C (36°F).

Sub-Objective 3: Measure the level of temperature distribution and thermal protection of four commercially available pallet covers with base protection. The covered mango pallets were exposed at a constant temperature of 2.2°C (36°F).

Sub-Objective 4: Analysis of critical areas throughout the pallet where the level of thermal protection is underperforming.

Method

Two pallets of Kent variety mangos were acquired from GM Produce Sales in Hidalgo, Texas. The mangos were picked up on July 5, 2017 from G.P.I in Tampa, Fl. The pallets measured 40x48x64 inches (1x1.2x1.6 m). They were 14 rows tall containing 15 cases per row. Each case contained 10 mangos, weighing approximately 9 lbs (4 kg) per case.

Mango pulp temperatures were measured at 23 locations inside each pallet in order to provide a full temperature distribution analysis. The locations included the 8 corners, 6 faces, and 9 internal points, see Figures 1 and 2. The instrumented mangos were on layers 1, 3, 7, 11 and 14. In addition, air temperature and relative humidity was measured on top of the pallets, under each cover.

Figure 1: Diagram of the Temperature Probed Mangos on All Corners and Pallet Faces

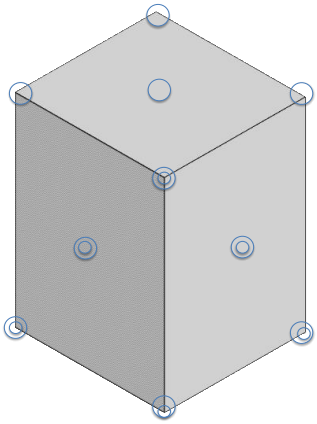
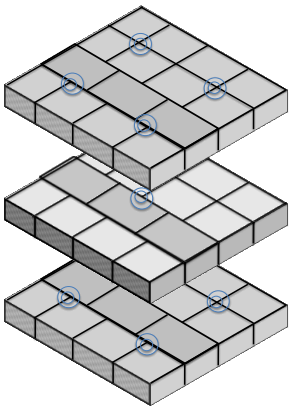


Figure 2: Diagram of the Temperature Probed Mangoes Inside the Pallet



The temperature probes were inserted into the pulp of the mangos at a depth of 1 inch (2.54 cm). Each measured mango weighed approximately 14.1 oz. (400 grams). The pulp temperature was recorded with HOBO® brand U12 data loggers (Onset Computer Corporation, Pocasset, MA, USA) that records within an accuracy of +/- 0.63°F (0.35°C) that were equipped with the temperature probe, TMC6-HD (Onset Computer Corporation, Pocasset, MA, USA) which records within an accuracy of +/- 0.9°F (0.5°C). The air temperature and humidity was measured under the cover with a HOBO® brand U12 data loggers (Onset Computer Corporation, Pocasset, MA, USA), which records within an accuracy of +/- 0.63°F (0.35°C). The data loggers were programmed with HOBOwarePro® (Onset Computer Corporation, Pocasset, MA, USA). The temperature loggers measured the temperature every minute.

Environmental temperature chambers were used to replicate similar environmental

conditions found during mixed load transportation. A Darwin environmental chamber (Darwin Chambers Company, St. Louis, MO, USA) with a temperature range of 14°F to 131°F (-10°C to +55°C) and a temperature control sensor at +/- 0.36°F (0.2°C) was used to conduct the testing. The temperature inside was recorded with HOBO® brand U12 data loggers (Onset Computer Corporation, Pocasset, MA, USA) that records within an accuracy of +/- 0.63°F (0.35°C).

Four commercially available pallet covers were used: DuPont™ Tyvek® W10 cargo cover, DuPont™ Tyvek® W50 cargo cover, metalized bubble wrap cover, and QProducts & Services (Qsales) white quilt cover. The cover specifications can be seen in the appendix. The pallets of mangoes were conditioned inside the environmental chambers set at 55°F (12.8°C) for at least 24 hours. Two pallets were tested at a time. The test pallet covers were placed on each pallet then exposed to the chamber set at 36°F (2.2°C) for 72 hours. For each cover tested, a second test was conducted with a base protection. To do this, each pallet had to be broken down and rebuilt.

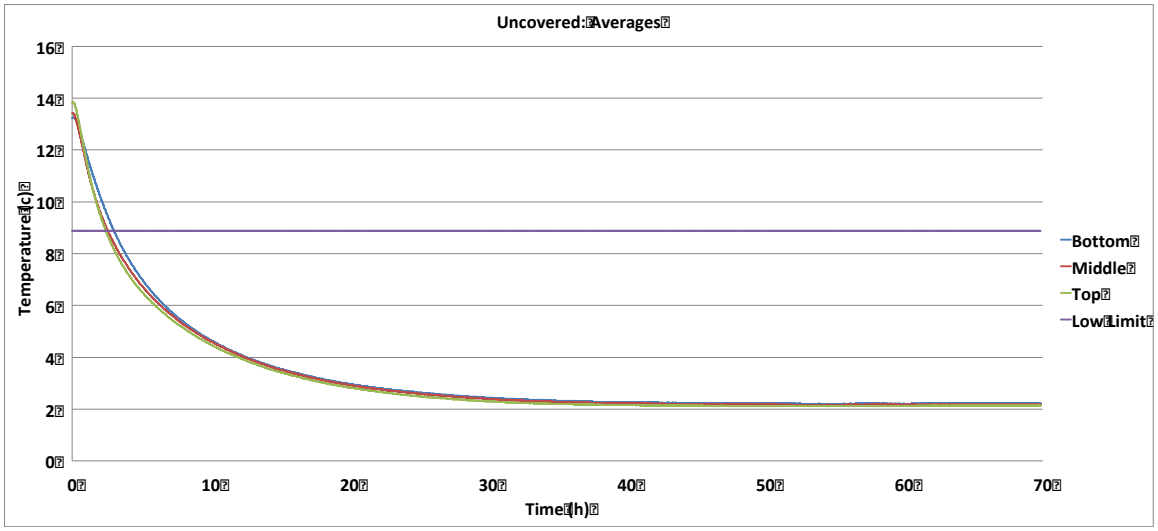
Results

The result graphs shown in the sub-objectives below demonstrate the average temperature distribution within each pallet. The bottom average is composed of layers 1 and 3. The middle is layer 7. The top is composed of layers 11 and 14. The averages were chosen in order to highlight the temperature changes, however the full data set can be seen in the appendix.

Sub-Objective 1

An uncovered mango pallet was tested in order to determine a baseline for temperature performance. The average temperature distribution within the uncovered mango pallet can be seen in Figure 3 below. The pulp temperature of the mangos fell below 48°F (8.9°C) within 2.1 hours. The most central internal point in the pallet took 7 hours to cool to the low limit threshold.

Figure 3: Average Temperature Results of Uncovered Mango Pallet



Sub-Objective 2

All four pallets that were tested with a cover that did not include a base reached colder temperatures in the bottom portion of the pallet compared to the middle and upper sections. None of pallets were able to maintain a temperature above 48°F (8.9°C) longer than 10 hours for mangos on the bottom section of each pallet. The metalized bubble wrap cover without a base and the W10 cover without a base yielded similar thermal results, see Figures 4 and 5. Both were not able to maintain the middle section's average temperature above 48°F (8.9°C) longer than 21 hours. On average, the top sections reached the low limit after 26-27 hours.

Figure 4: Average Temperature Results of Metalized Bubble Wrap Cover without Base

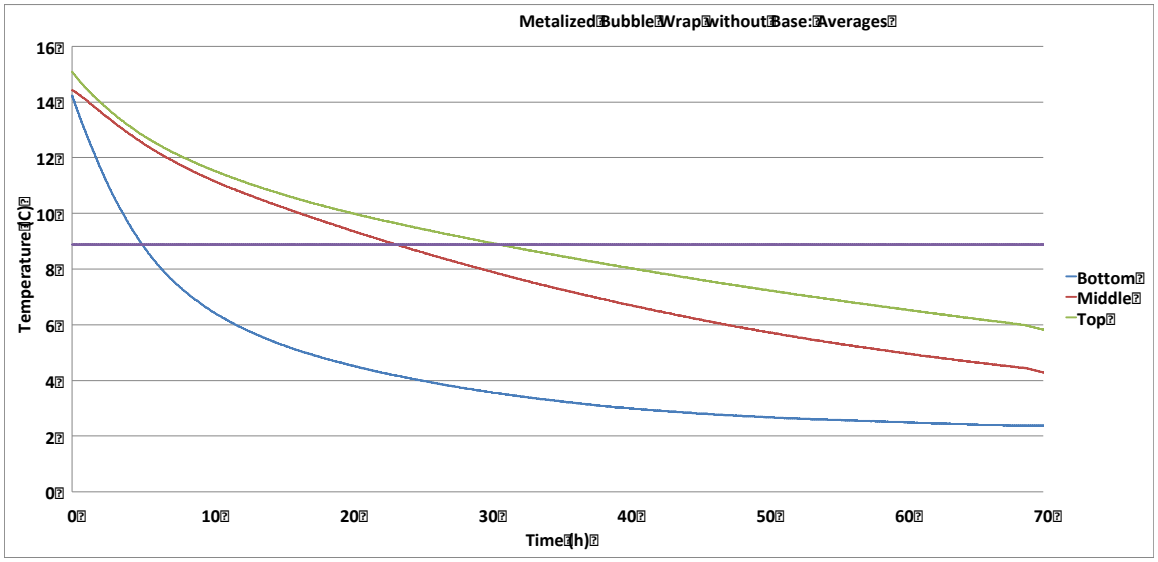
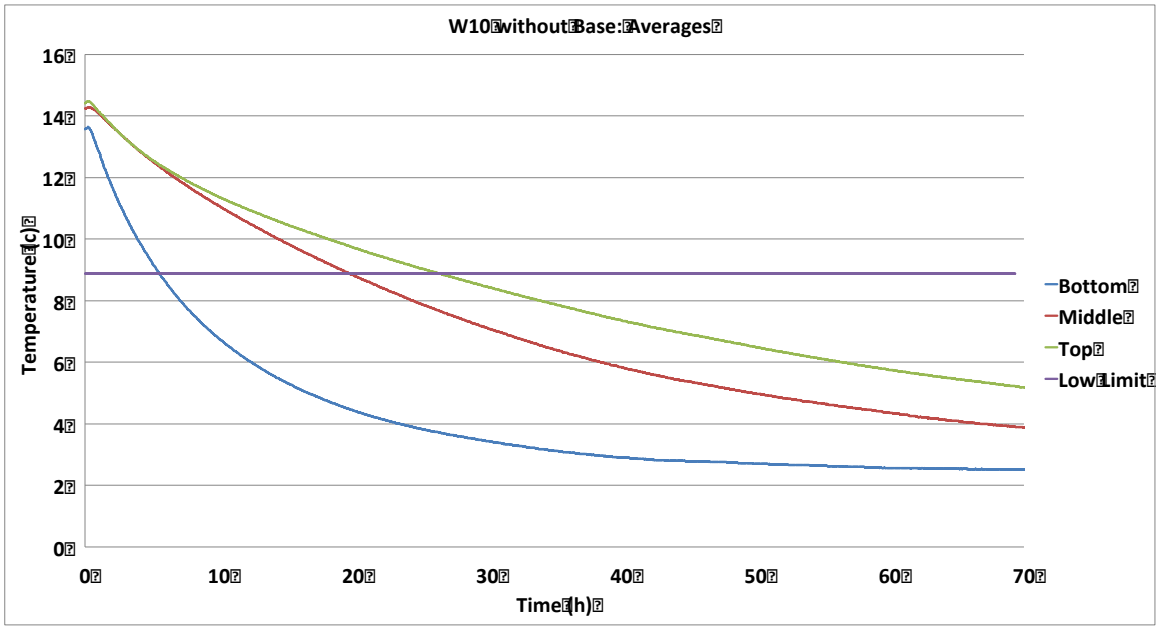


Figure 5: Average Temperature Results of DuPont W10 Cover without Base



The relative humidity under metalized bubble wrap cover without a base and the W10 cover without a base differed. The metalized bubble wrap had a relative humidity above 95% and the W10 cover had a relative humidity of 85%. The pallet covered in the metalized bubble wrap had significant condensation on the cases and the mangos, which could lead to a more rapid decay and allow for mold growth, see Figure 6. The pallet covered with the W10 cover seemingly allowed the water vapor to evaporate,

thus maintaining a dryer mango with less free water collection.

Figure 6: Condensation on Mangos and Cases Under the Metalized Bubble Wrap Cover

The Qsales white maintained the middle section's average temperature above 48°F (8.9°C) temperature for 26.6 hours. The top section reached the low limit after an average of 58.1 hours, Figure 7. The W50 cover maintained the middle section's average temperature above 48°F (8.9°C) temperature for 45.2 hours. The top section reached the low limit after an average of 66 hours, Figure 8.

Figure 7: Average Temperature Results of Qsales White Cover without Base

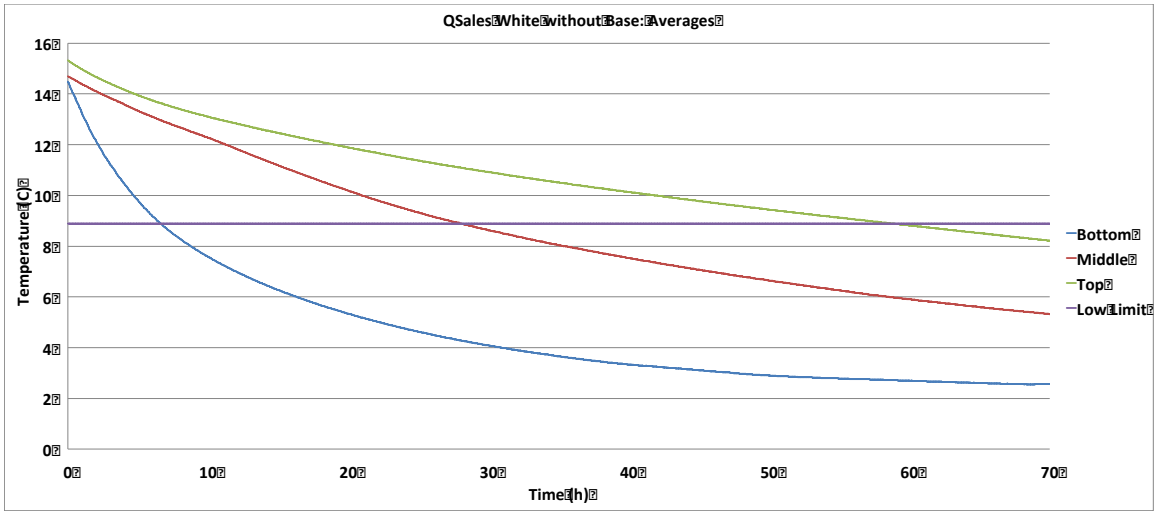


Figure 8: Average Temperature Results of DuPont W50 Cover without Base

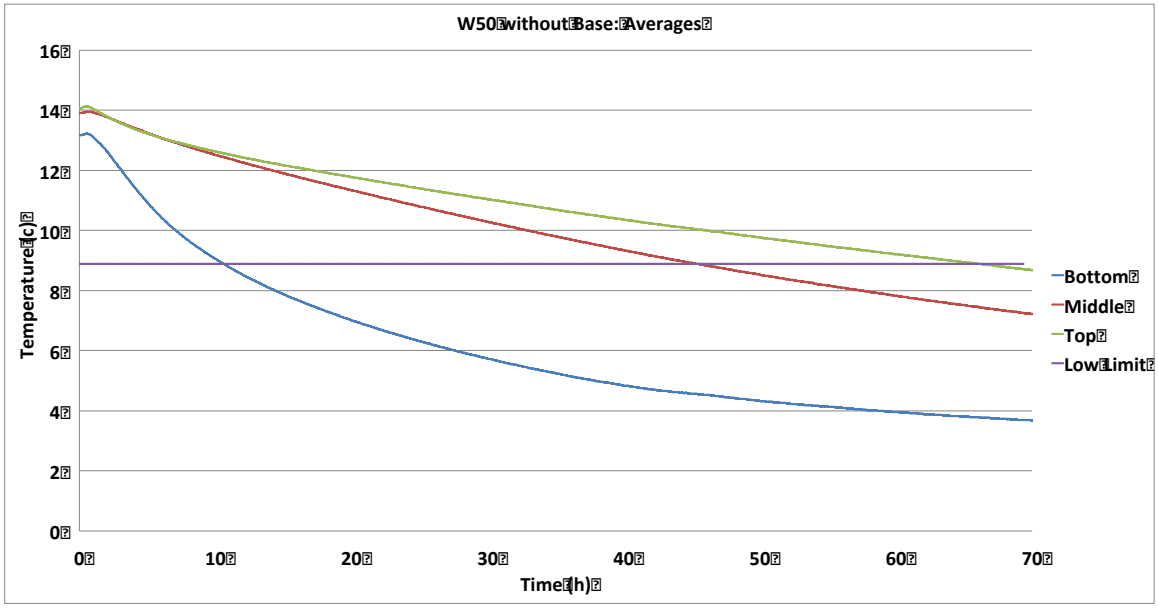


Table 1: Average Time (hr) per Pallet Section to reach 48°F (8.9°C)

Pallet Section	Metalized Bubble Wrap without Base	Qsales White Cover without Base	W10 cover without Base	W50 cover without Base	Uncovered
Bottom	4.1	6.5	5.2	10.3	2.8
Middle	21.3	27.8	20.2	45.1	2.3
Top	28.1	58	27.4	66.1	2.3

Sub-Objective 3

For all four pallets, the bottom cases of mangos within each pallet did not see significant thermal improvement when they were tested with a base compared to without a base. The bottom mango case temperatures only lasted an average of 3.5 hours longer before reaching 48°F (8.9°C) with the addition of a base. The metalized bubble wrap with a base and W10 cover with a base experienced similar thermal performances to those tests conducted without a base. On average, among all pallet sections an improvement of 1.3 hours was seen with the metalized bubble wrap and 1.9 hours was seen with the W10 cover. The metalized bubble wrap cover with a base and W10 cover with base thermally protected the top 2/3 of the pallet for approximately 25.2 hours, Figures 9 and 10.

Figure 9: Average Temperature Results of Metalized Bubble Wrap Cover with Base

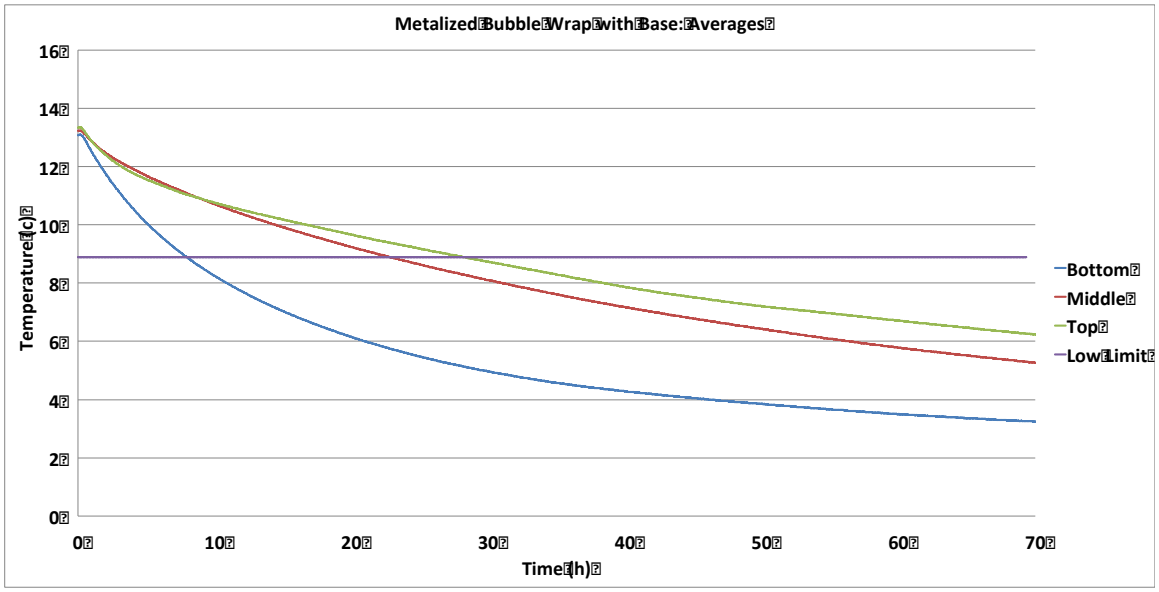
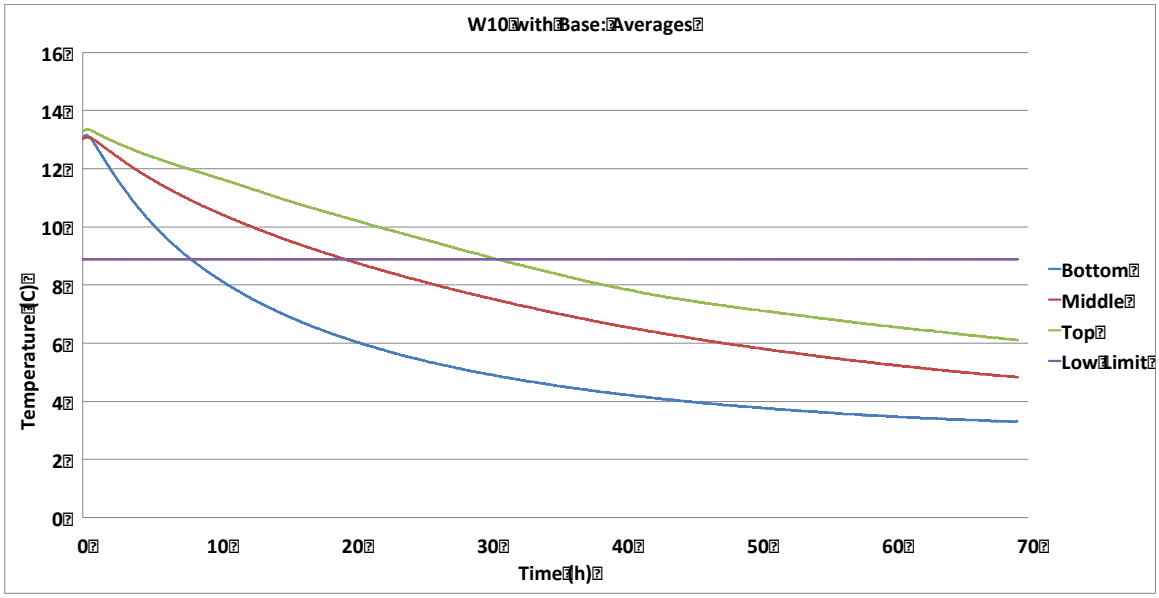


Figure 10: Average Temperature Results of DuPont W10 Cover with Base



The metalized bubble wrap with a base had a completely saturated relative humidity and W10 cover with base had a relative humidity of 85%. The pallet covered in the metalized bubble wrap had a significant amount condensation on the cases and the mangos, which could lead to a more rapid decay and allow for mold growth, Figure 11.

Water accumulated at the base of the pallet. The pallet covered with the W10 cover allowed the water vapor to evaporate, thus maintaining a dryer mango with less condensation.

Figure 11: Condensation on Mangos and Cases with the Metalized Bubble Wrap Cover with Base

The addition of a base prolonged the temperature maintenance in pallets using the Qsales white cover and the W50 cover. On average, among all pallet sections an improvement of 4.2 hours was seen with the Qsales white cover with base and 5.9 hours was seen with the W10 cover with base. The middle section of the Qsales white cover with base lasted 36.7 hours, where the W50 cover with base lasted 54.1 hours. The top section of the Qsales white cover with base lasted 58.8 hours, where the W50 cover with base lasted 70 hours. The W50 cover with base allowed the upper 2/3 of the pallet to remain above 48^{o}F (8.9^{o}C) for an average of 62 hours, allowing for the 2-day transit time, see Figures 12 and 13.

Figure 12: Average Temperature Results of Qsales White Cover with Base

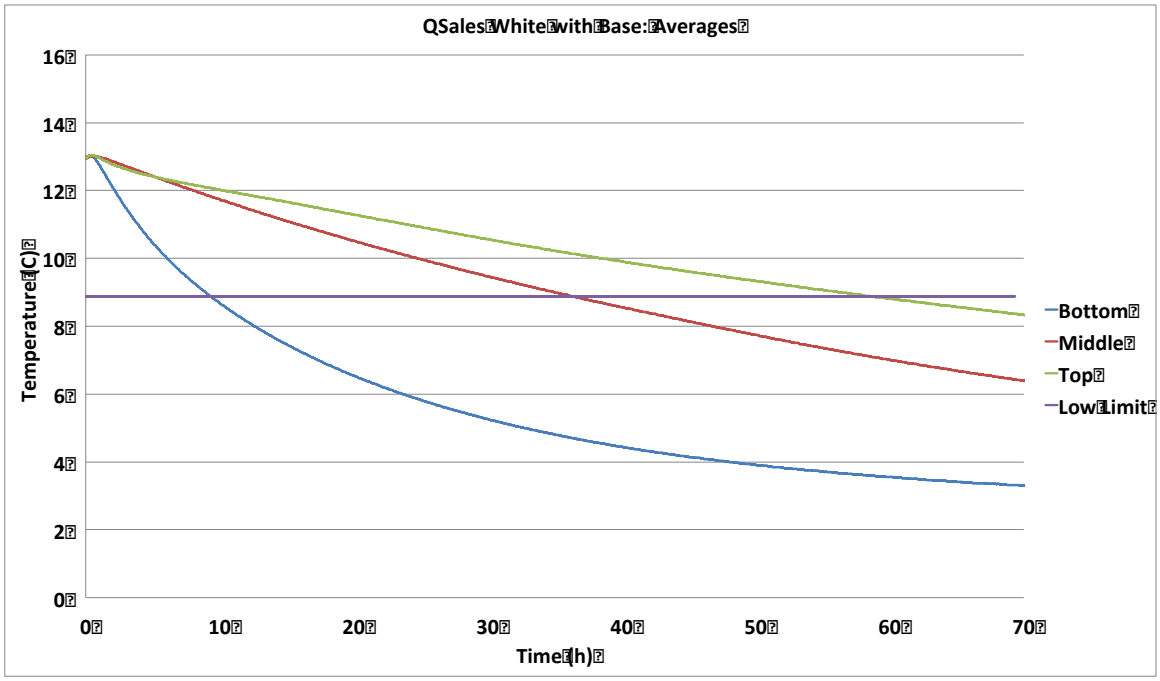
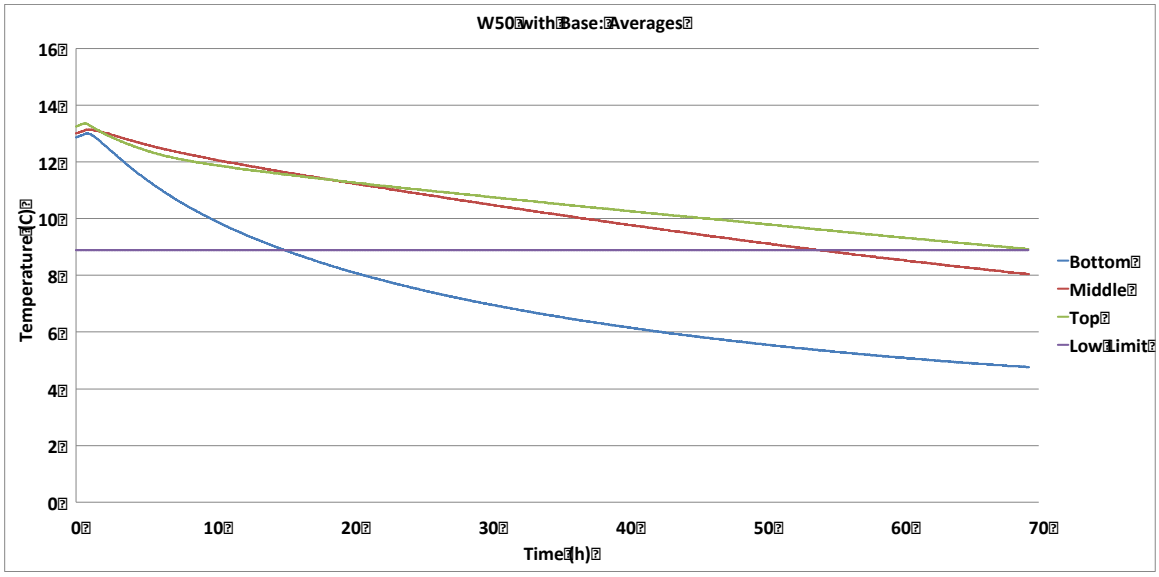


Figure 13: Average Temperature Results of DuPont W50 Cover with Base



The relative humidity seen under the Qsales white cover with base was

measured at 95%, however the covers' material allowed the free water to be absorbed, thus producing less water on the mangoes than seen in other Qsales white cover or bubble wrap tests. The W50 cover with base had the lowest measured relative humidity out of all tested covers at 80%. Condensation was not visible on the mangos covered with the W50 with base.

Table 2: Average Time (hrs.) per Pallet Section to reach 48°F (8.9°C)

Pallet Section	Metalized Bubble Wrap with Base	Qsales White Cover with Base	W10 cover with Base	W50 cover with Base	Uncovered
Bottom	7.5	9.5	7.75	15	2.8
Middle	22.4	36.7	19.45	54.1	2.3
Top	27.6	58.8	31.35	70	2.3

Figures 14 to 18 present the three-dimensional temperature distribution in a pallet of mangos using a thermal cover with a bottom during exposure at 36°F (2.2°C) during 72 hours.

Figure 14: Representation of the three-dimensional temperature distribution in a pallet of mangos and temperature color code.

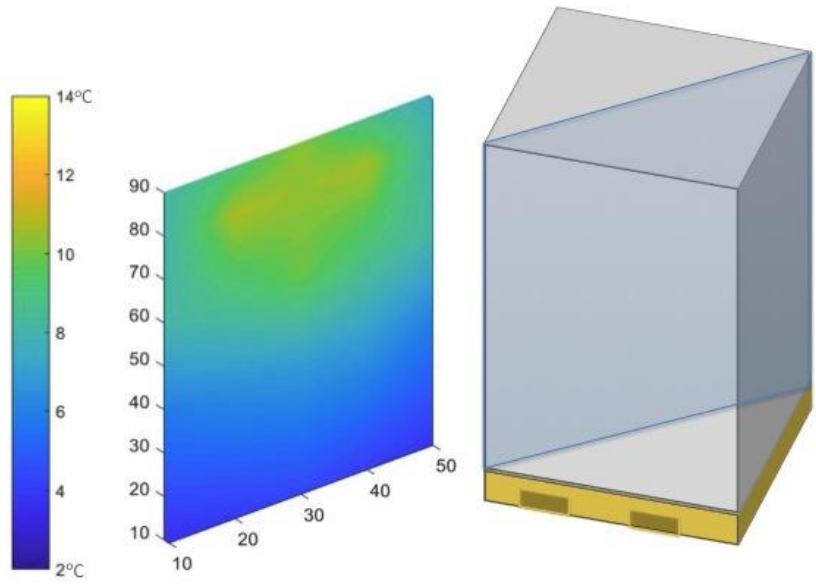


Figure 15: Three-dimensional temperature distribution in a pallet of mangos using the DuPont W10 thermal cover with a bottom during exposure at 36°F (2.2°C) during 72 hours.

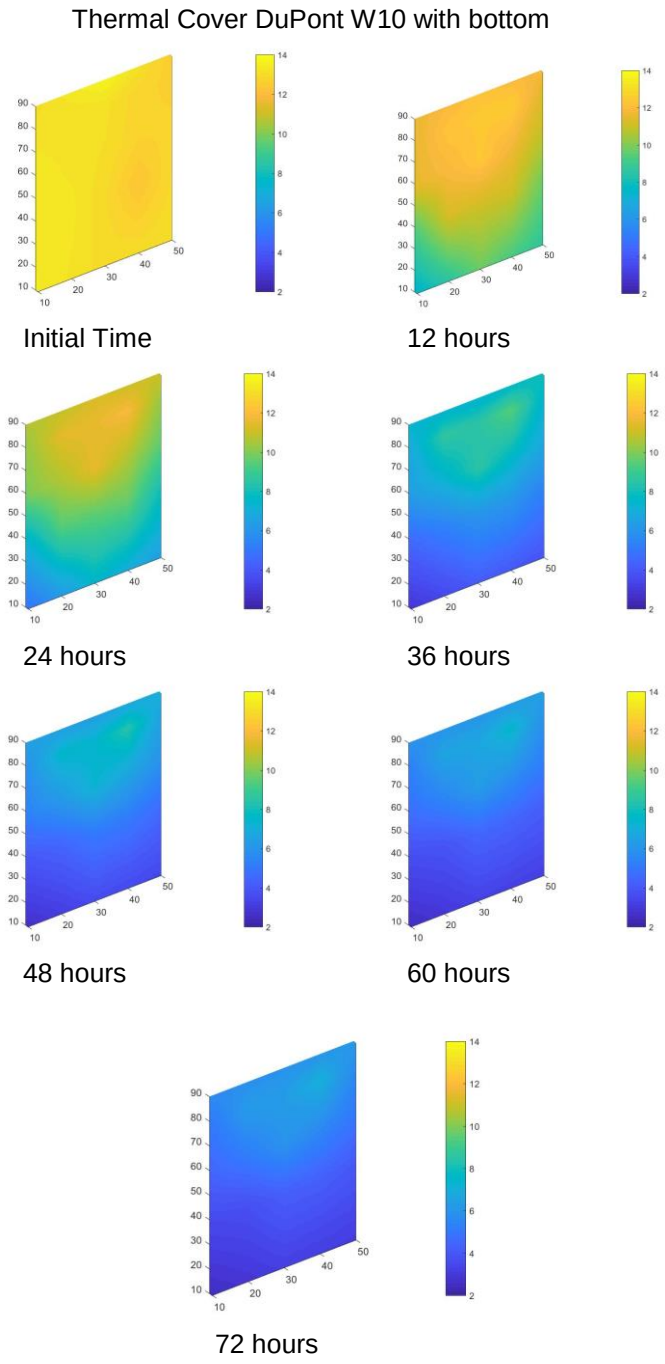


Figure 16: Three-dimensional temperature distribution in a pallet of mangos using the DuPont W50 thermal cover with a bottom during exposure at 36°F (2.2°C) during 72 hours.

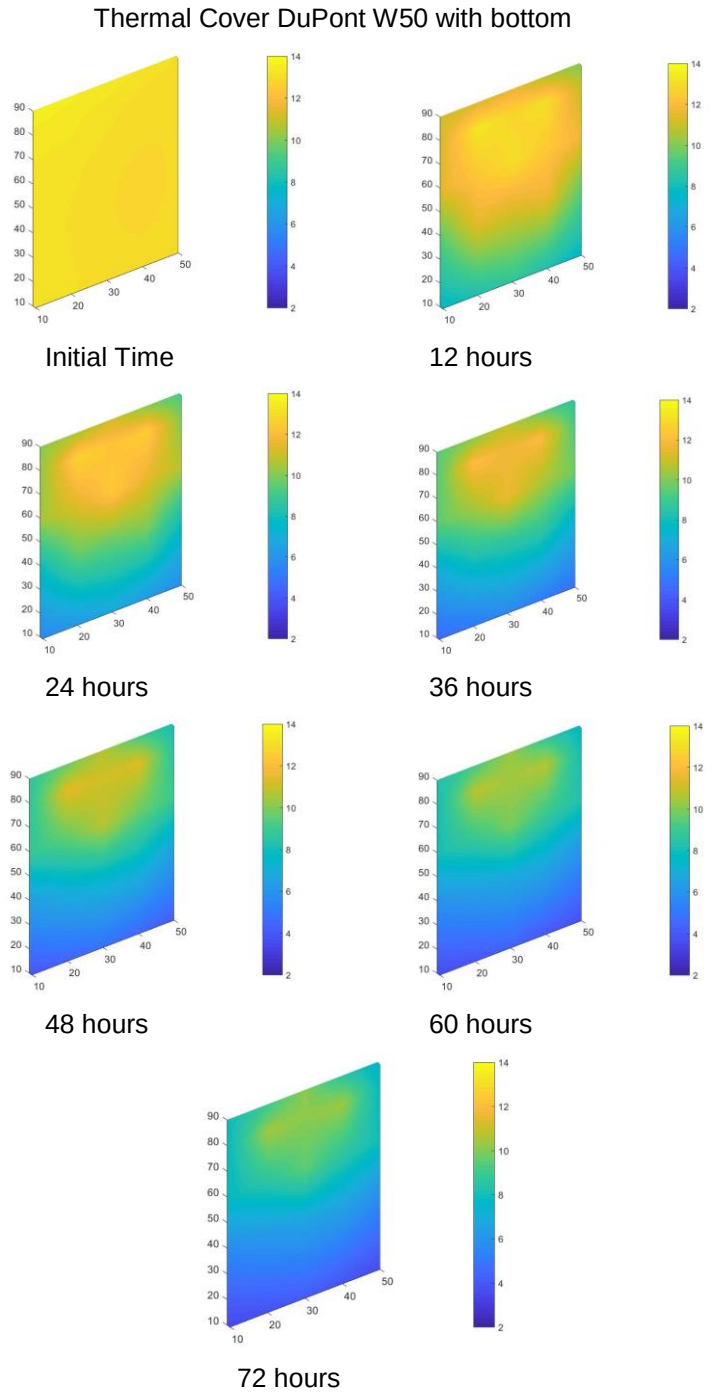


Figure 17: Three-dimensional temperature distribution in a pallet of mangos using the Bubble Wrap thermal cover with a bottom during exposure at 36°F (2.2°C) during 72 hours.

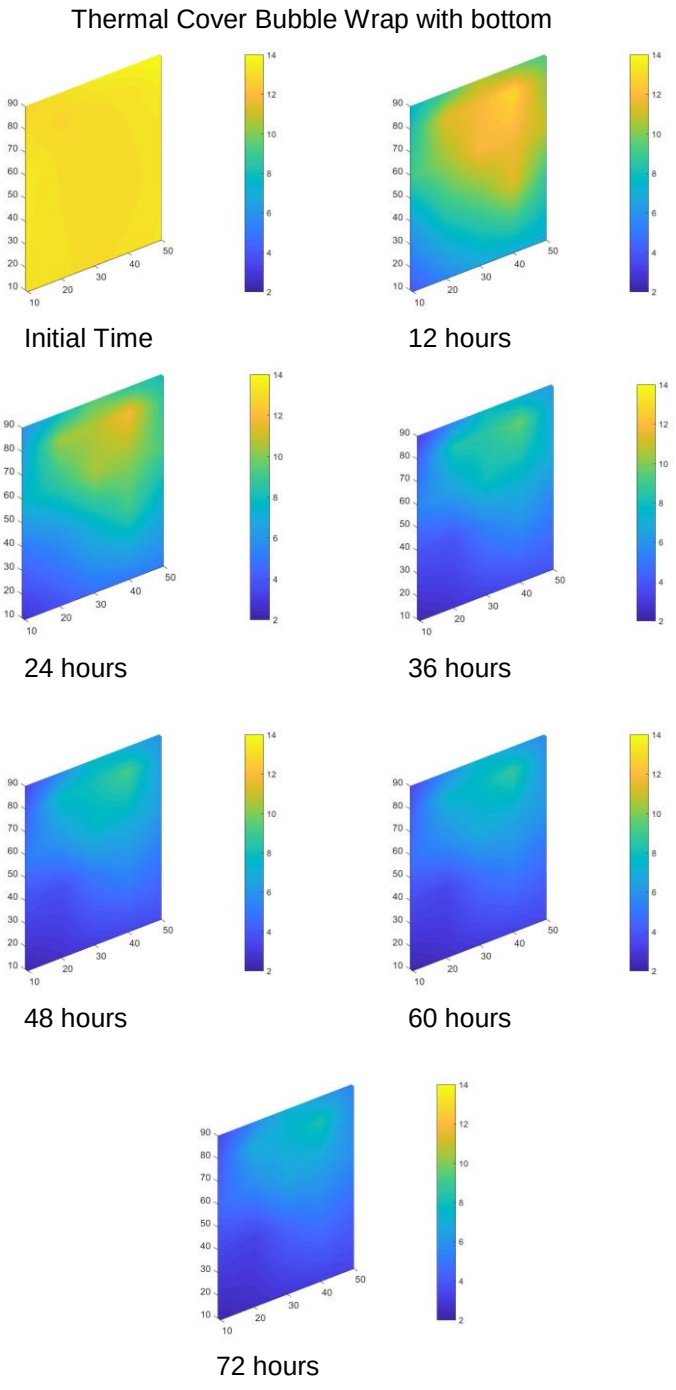
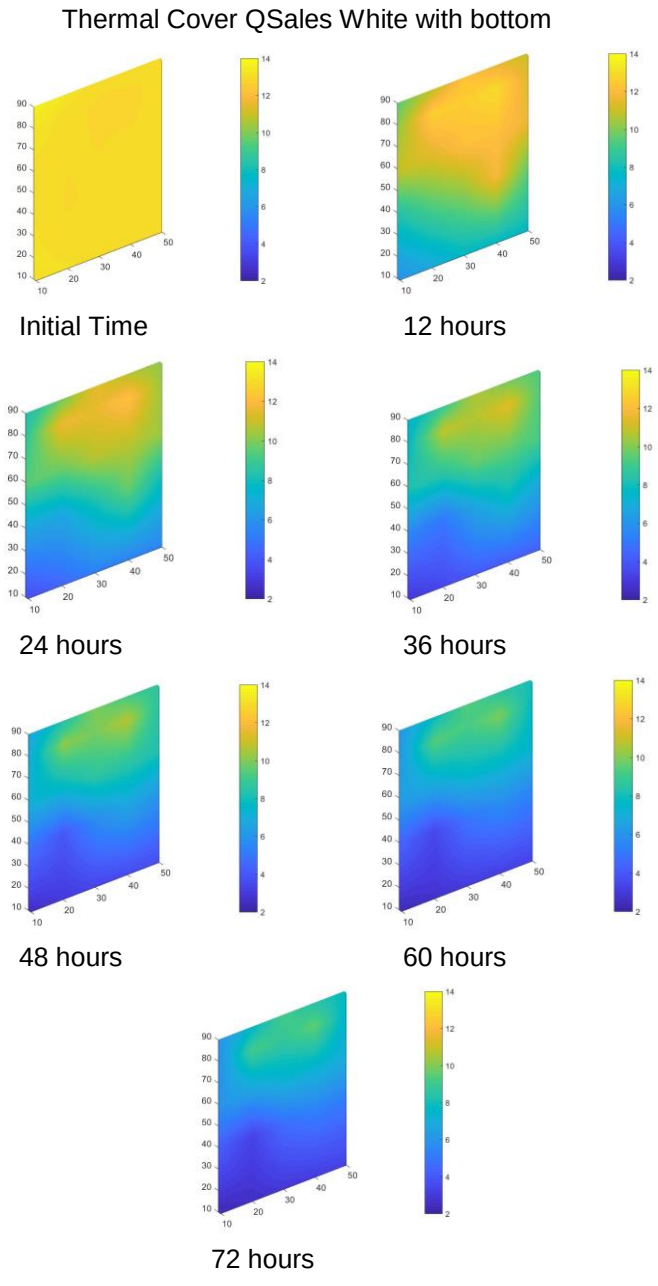


Figure 18: Three-dimensional temperature distribution in a pallet of mangos using the Qsales White thermal cover with a bottom during exposure at 36°F (2.2°C) during 72 hours.

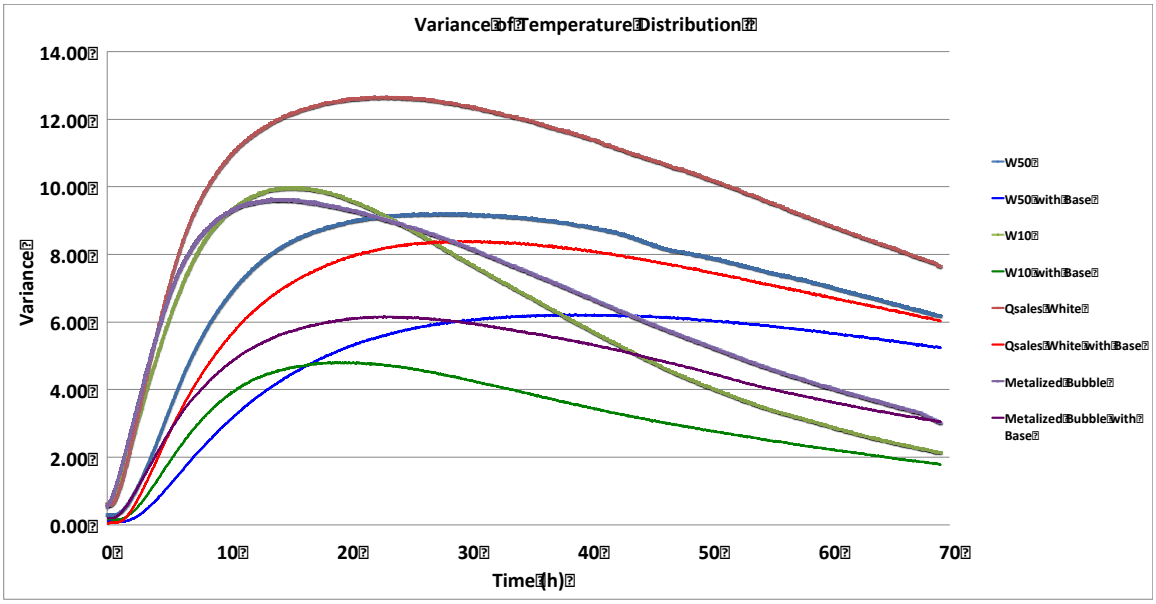


Sub-Objective 4

On all tested pallets, the most critical area for cold temperature deviations was on cases near the bottom of the pallet. The top sections of the pallets demonstrated the warmest temperatures. In order to properly compare the effectiveness of each cover type, the pallets were arranged in the environmental chamber with air gaps on all 6 faces. None of the tests allowed the pallets to touch each other or the walls, therefore temperature data was generally consistent on all sides. However, in a real life shipping environment pallets could touch walls and other pallets. Critical temperature measurement points would be on faces that were exposed to air gaps or on faces that touched walls or other pallets containing cold items. To detect for chilling injury, it would be best to test the mangos on the bottom level of the pallet.

On all the tested pallets, the addition of a base created a more uniform temperature distribution. Uniform temperature distributions can results in a more consistent mango quality level throughout the pallet. For example, mangos at the top of the pallet are more likely to have a similar shelf life to mangos in the center. Figure 14 below indicates the variance of each cover type, measuring the spread of the temperature distributions. The W50 cover had the least difference, therefore would give the most consistent temperature distribution if used with or without a base as well as providing the best temperature protection. The Qsales white cover without a base demonstrated the widest temperature difference throughout the pallet, therefore would give the most inconsistent temperature distribution. The W10 cover with base and metalized bubble with base exhibited the good results for temperature distribution, however, did not adequately protect the mangos from temperature abuse. Covers with low temperature variance would provide for more efficient quality control testing, as the mango quality level would be similar throughout the entire pallet. The quality level could be good or bad dependent on all the other variables.

Figure 19: Temperature Distribution Variance Indicating Consistency of Mango Quality Level



The test results have shown that all the tested covers, both with and without bases do not fully protect the bottom layer of mangos from reaching temperatures below 48°F (8.9°C) for 48 hours. It can be presumed that a non-compressible insulation, such as Styrofoam could be added between the bottom case of mangos and the pallet in order to reduce the time the bottom layer reaches 48°F (8.9°C). The feasibility of this addition may not be realistic but could help reduce the cold airflow.

Discussion

The use of a base with any of the tested covers provided better thermal protection compared to the pallets tested without a base. It can be assumed that the cause of this was due to the production of heat by the mangos. The use of a base allowed the heat to be contained inside the pallet more. Contrasting to the baseless pallets, where airflow was able to penetrate the mangos easier and faster, causing temperature decreases to occur more rapidly. The use of a base also decreased the variability in temperature differences throughout the entire pallet. Consistent temperatures throughout the pallet can correlate to consistent levels of mango quality. However, the use of a base was a disadvantage for the metalized bubble wrap cover because it was not breathable, allowing significant condensation to occur on the

mangos, wet the cases, and accumulate water at the bottom of the pallet.

The visible effects of chilling injury intensify with prolonged exposure to low temperatures. The W50 cover with base was able to protect the top 2/3 of the pallet from temperatures below 48°F (8.9°C) for an average of 62 hours. Even though the bottom section went below 48°F (8.9°C), the exposure might have caused less severe chilling injury since the mangos were above 44°F (6.5°C) for 24 hours. The less extreme cold temperature and shorter duration of exposure in comparison to other tested pallets, may results in less chilling injury damage. Any pallet in direct contact with a cold surface, such as a trailer wall or colder adjacent pallet could cause the mangos to become too cold. It would be recommended that the mango pallets do not touch the trailer walls or cold pallets, instead provide an air gap.

Test results demonstrated the W50 cover with base to be the best option in terms of thermal and moisture protection. Therefore, it underwent additional testing in order to further enhance the covers performance. A new TTx prototype wrapping technology, provided by Illuminate was added under the W50 cover to aid in distributing the temperature. The TTx technology consists of wrapping materials that cover the pallet (but installed under a thermal cover) that allow the heat to move quicker in order to create a more uniform temperature distribution and eliminate heat and cold spots found under any thermal covers. The temperature protection was optimized by using the heat generated by the mangos to help maintain a warmer temperature in the inherently colder sections of the pallet. The test results demonstrated that the upper 2/3 of the pallet never went below 52°F (11°C) for the entire 72 hour testing duration, as seen in Figure 15. The bottom section remained above 45°F (7°C) for 48 hours and above 43°F (6°C) for 72 hours. A majority of the pallet remained in the desired range for a full 72 hours. The critical bottom section had a reduced temperature and time exposure, probably resulting in less chilling injury. The combination of the new technology and the W50 cover exhibited the best results. TTx technology is currently not available for large pallet sizes (72 inches high) but will probably be available in 2018.

Figure 20: Average Temperature Results of W50 Cover with Base combined with Illuminate TTx technology

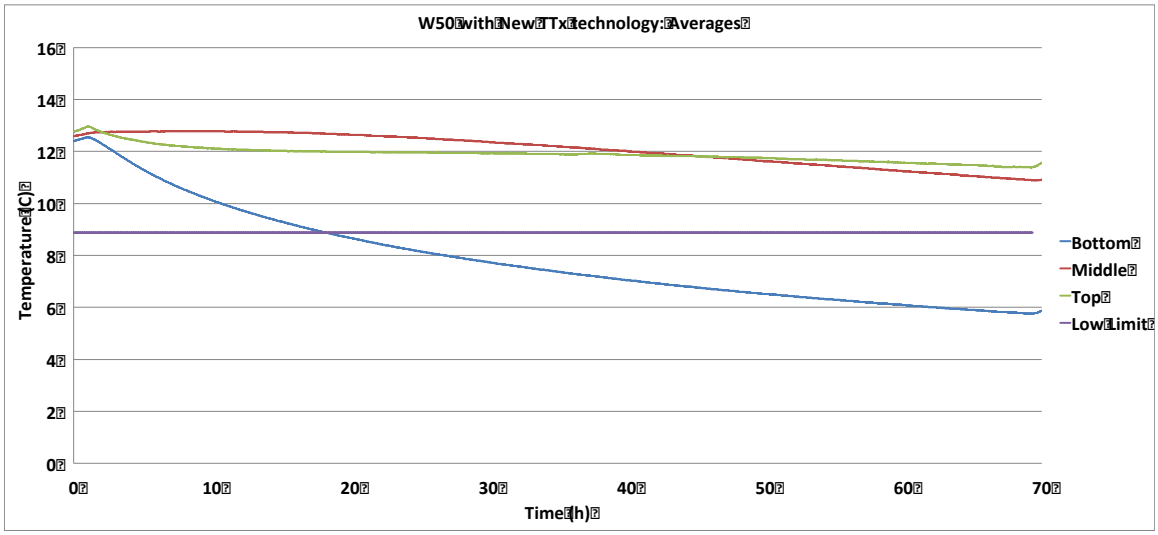
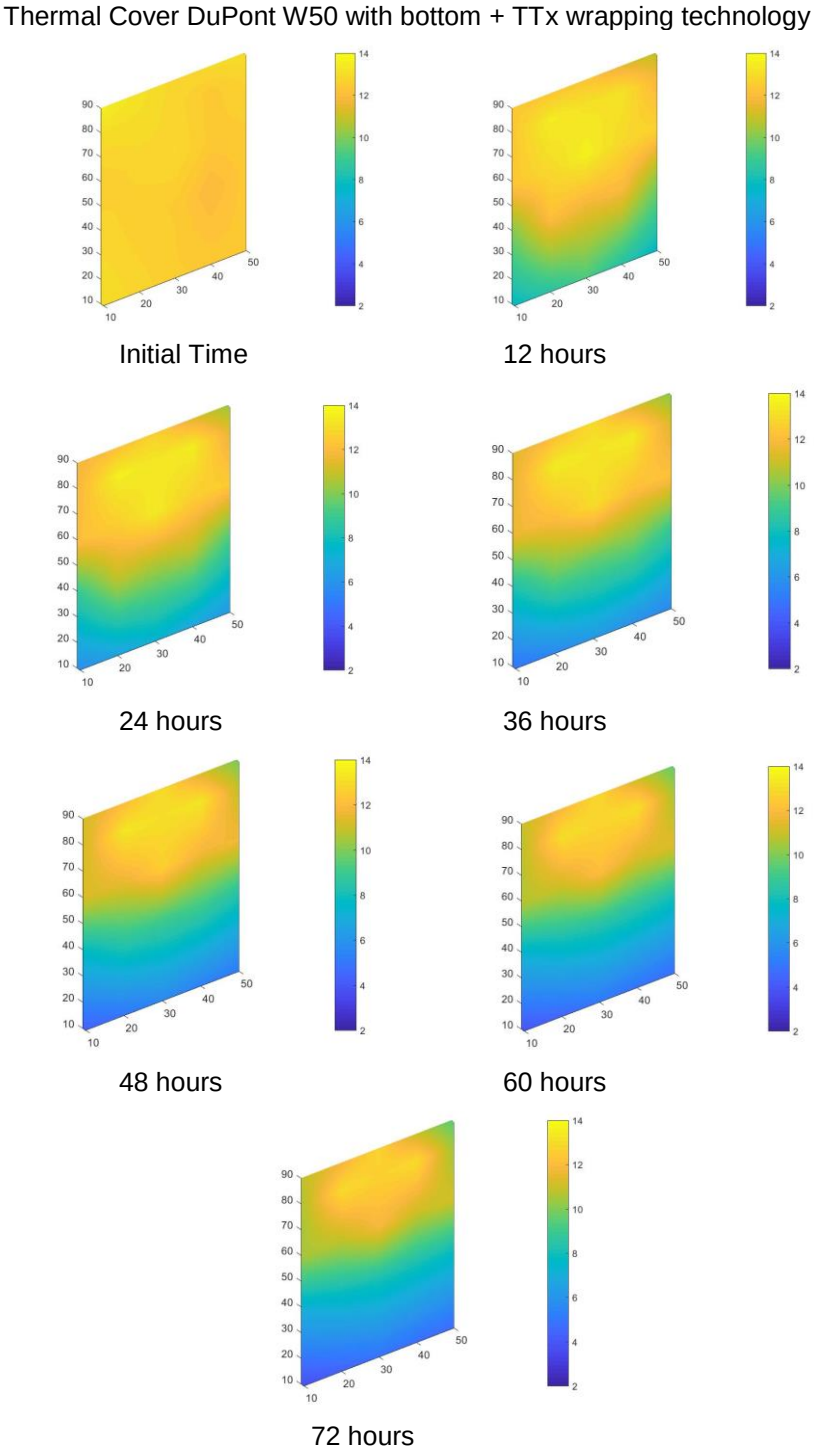


Figure 21 presents the three-dimensional temperature distribution in a pallet of mangos using DuPont W50 thermal cover with a bottom combined with a wrapping of the Illuminate TTX technology during exposure at 36°F (2.2°C) during 72 hours.

Figure 21: Three-dimensional temperature distribution in a pallet of mangos using DuPont W50 thermal cover with a bottom combined with a wrapping of the Illuminate TTx technology during exposure at 36°F (2.2°C) during 72 hours.

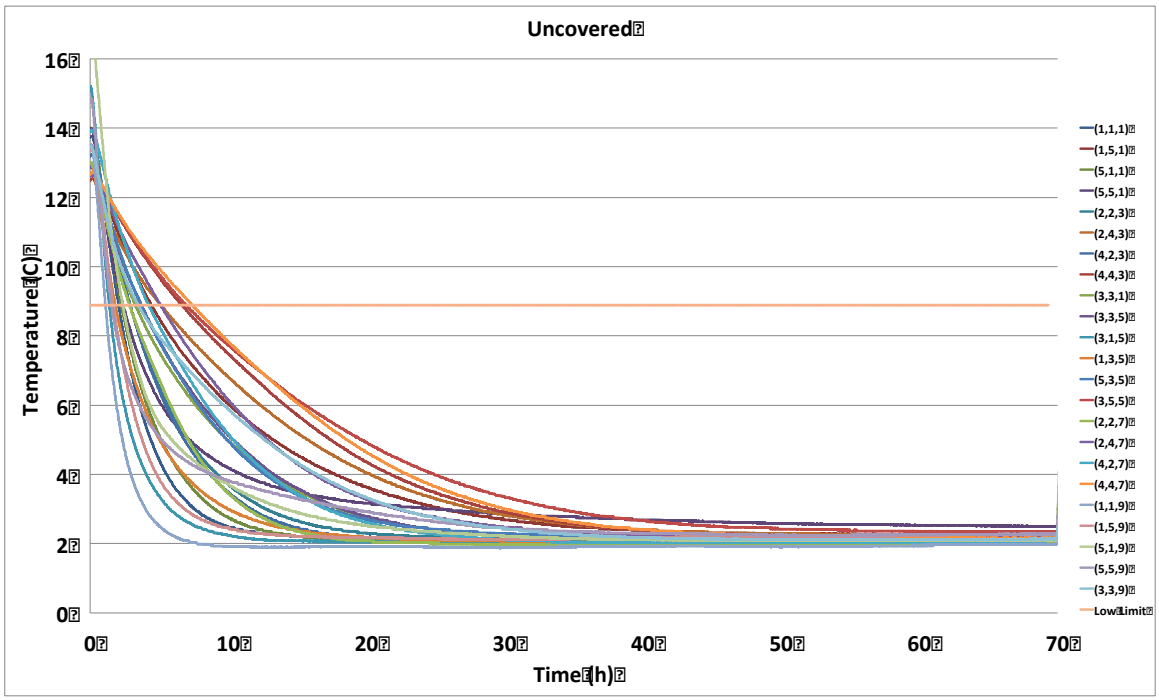


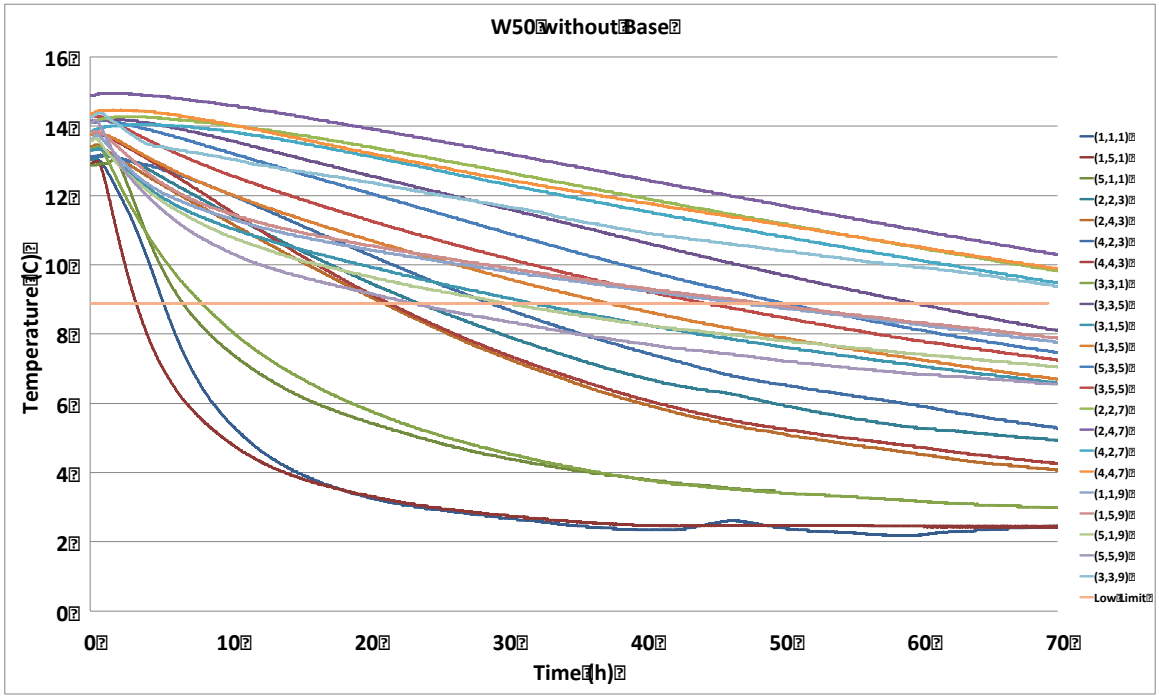
Conclusion

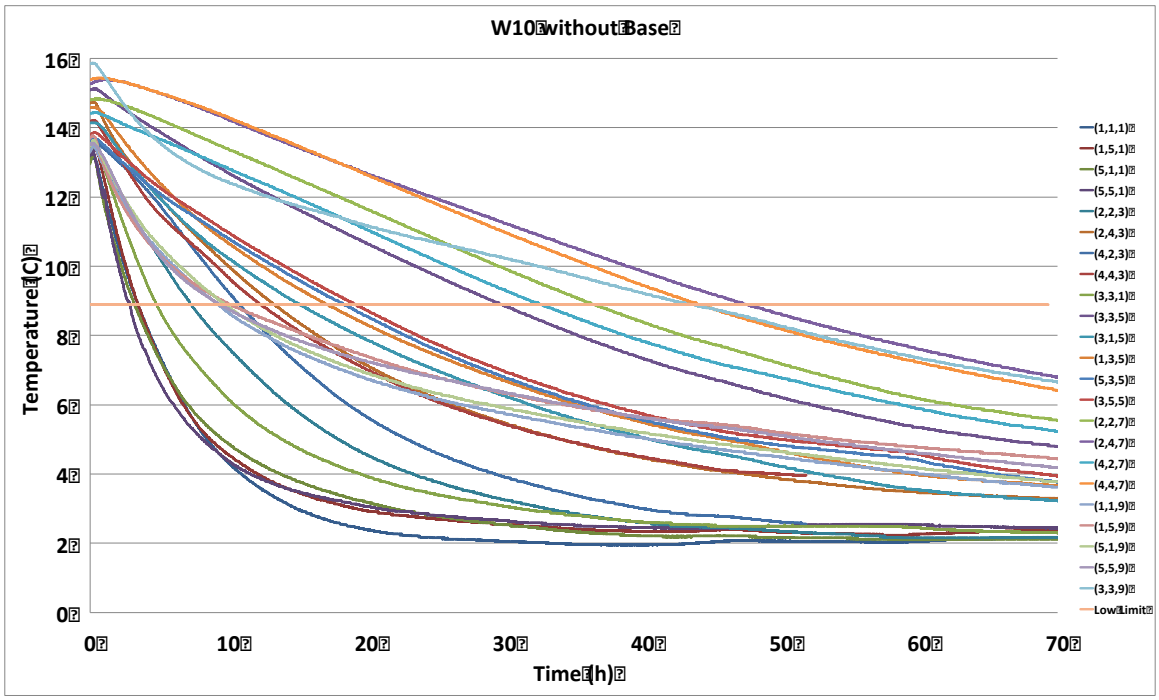
Four commercially available pallet covers were tested with and without a base to determine their thermal protection for pallets of mangos. None of the covers were able to maintain the entire pallet above 48^{o}F (8.9^{o}C) for entire 72 hour testing duration. However, the W50 cover with base has shown to be the best option in terms of thermal and moisture protection out of the four commercially available pallet covers. The top 2/3 of the pallet covered with the W50 cover was protected from temperatures below 48^{o}F (8.9^{o}C) for an average of 62 hours. Even though the bottom section went below 48^{o}F (8.9^{o}C), the severity of the exposure was above 44^{o}F (6.5^{o}C) for 24 hours. It is anticipated that in a real life shipping environment where the pallets have a few touching faces, that the W50 cover would provide even more temperature protection. Additional usage of new technologies combined with existing pallet covers may allow for a better performance, thus protecting the entire pallet from chilling injury for 72 hours.

Appendix

Comprehensive Temperature Results






W10 without Base
Temperature (°C)
Time (h)
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
(1,1,1)
(1,5,1)
(5,1,1)
(5,5,1)
(2,2,3)
(2,4,3)
(4,2,3)
(4,4,3)
(3,3,1)
(3,3,5)
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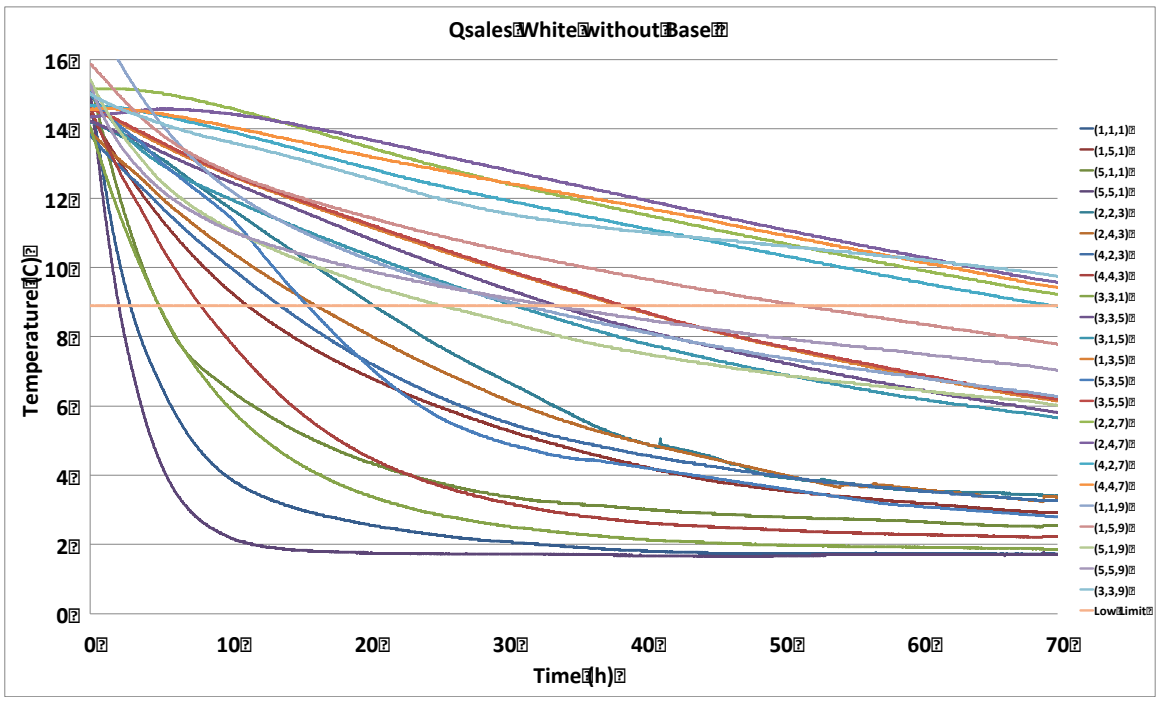
(5,5,9)
(3,3,9)
Low Limit


Qsales White without Base
Temperature (°C)
Time (h)
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
(1,1,1)
(1,5,1)
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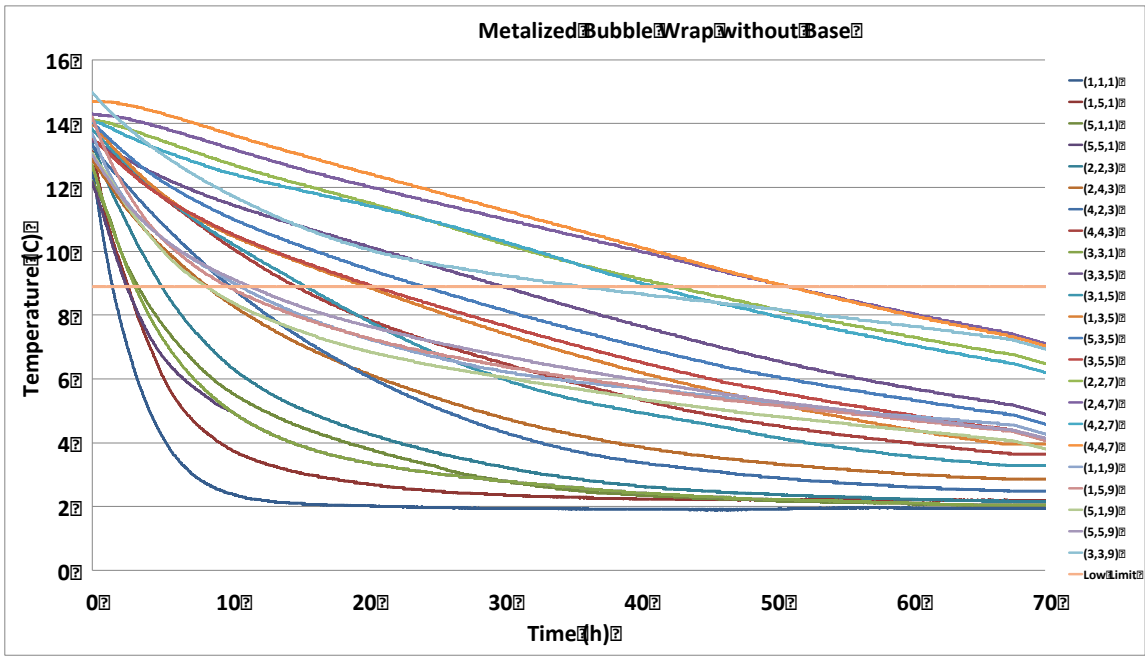
Metalized Bubble Wrap without Base
Temperature (C)
Time (h)
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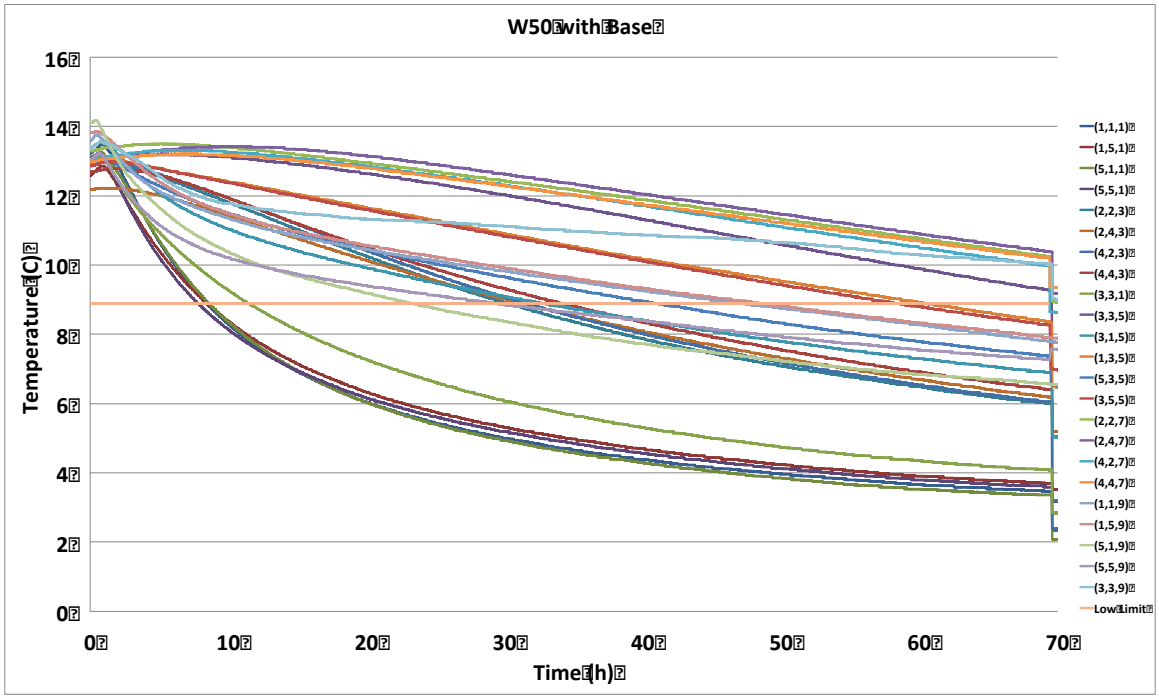
W50 with Base
Temperature (C)
Time (h)
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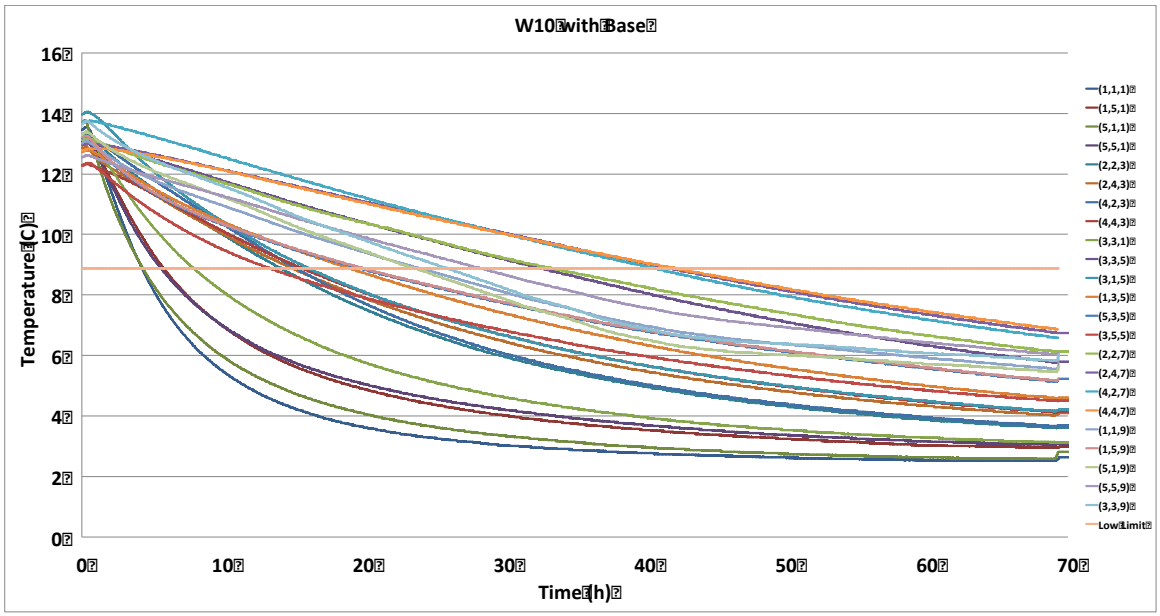
W10 with Base
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Time (h)
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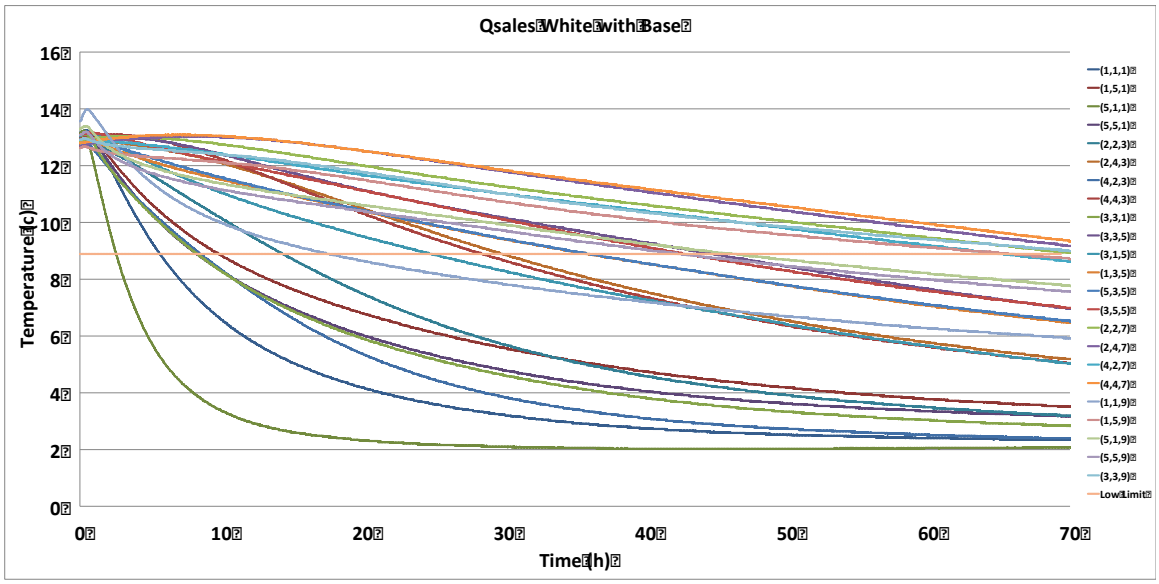
Qsales White with Base
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Time (h)
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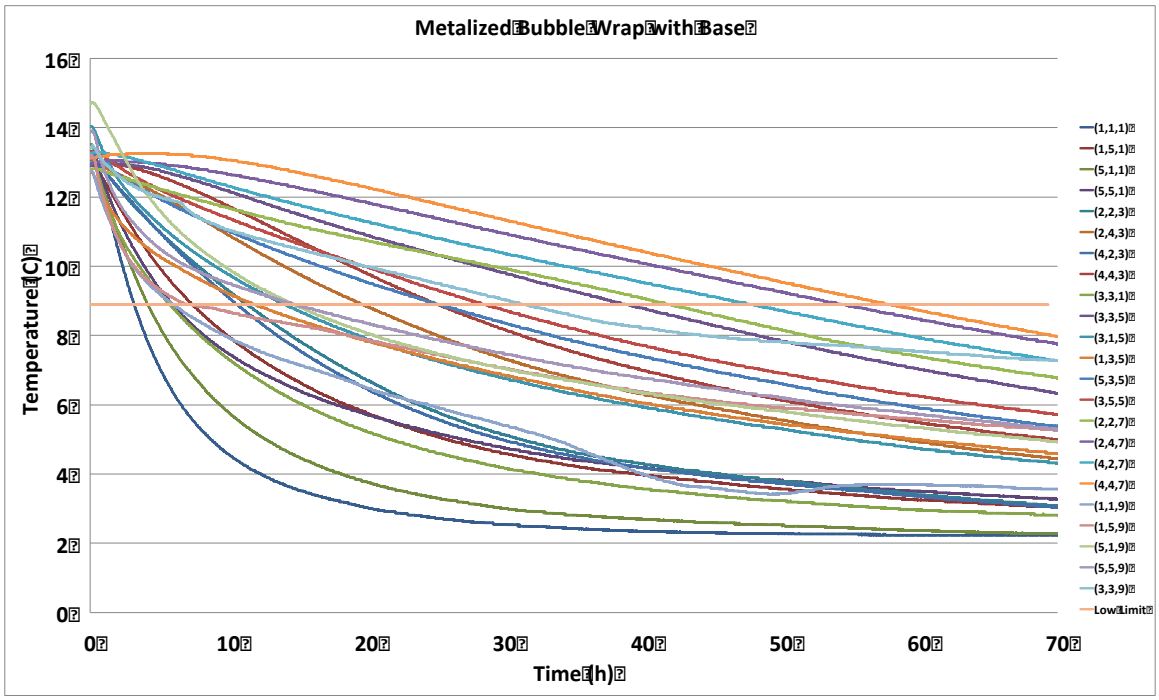
Metalized Bubble Wrap with Base
Temperature (C)
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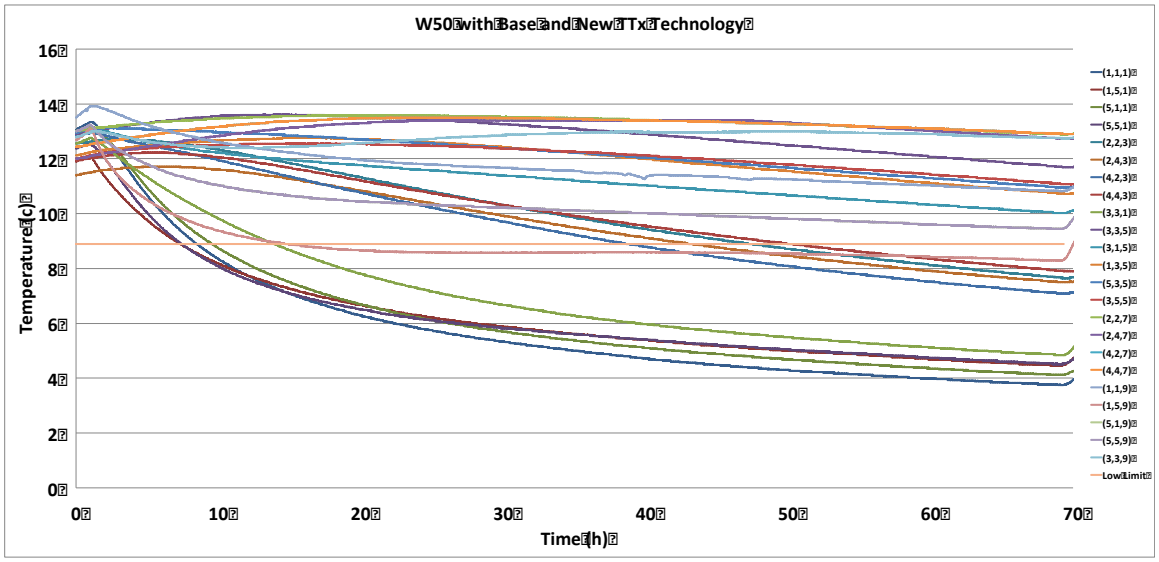
W50 with Base and New Tx Technology
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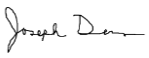
DuPont™ Tyvek® Cargo Covers

DEVELOPMENTAL TECHNICAL DATA & DOCUMENTATION

TEST DATA OF TYVEK® CARGO COVERS FOR PHARMACEUTICALS, PERISHABLES AND TEMPERATURE SENSITIVE PRODUCTS

Reviewed and approved by:	Alain Weimerskirch  Application Development Specialist	Date: 11 Aug 2016
Reviewed and approved by:	Joseph Dennes  Global Technology Manager	Date: 11 Aug 2016
Document number and name:	Developmental_Technical_Data_&_Documentation_Tyvek®_Xtreme™_W50_Cargo_Cover	
Version:	1.0	
Related documents:	n/a	

DuPont™ Tyvek® Xtreme™ W50 Cargo Cover

Solar protection, cold temperature performance and breathability - Tyvek® Xtreme™ W50 Cargo Cover successfully combines these triple benefits. It sandwiches a low-emissivity metallic layer between high efficiency insulation on the inside and highly reflective, weatherproof, Tyvek® on the outside. The product is suitable for cool-chain handling environments and shipping lane scenarios where there is a possibility of transient exposures to low ambient temperatures and for any long or complex transportation routes where there is a likelihood of significant temperature variations, especially those where there is potential for short-term exposure to the sun.

Product data sheet

Property	Value	Test method
Basis weight[1]	330 g/m^2 ± 15 g/m^2	DIN EN ISO 536 (96)
Tensile Strength*[2]	MD 155 ± 25 N/5cm	EN 12311-1 (99)
	XD 130 ± 20 N/5cm	
Tensile Elongation*[2]	MD 9% ± 3%	EN 12311-1 (99)
	XD 14% ± 5.5%	
Tear Resistance (nail shank) *[2]	MD 60 ± 20 N	EN 12310-1 (99)
	XD 55 ± 15 N	
Emissivity*	16% ± 6%	ASTM C1371
Light reflection (400 – 700 nm)*	91.3% ± 3%	ASTM E1164
Moisture Vapor Transmission*[3]	1300 ± 600 g/m^2/24h	DIN EN ISO 12572 C
Water pressure (Hydrostatic Head)*[4]	>140 cm H_2O	DIN EN 20811 (92)
Resistance to penetration of water*[2]	W1 PASS	DIN EN 1928-A (00)
Thermal conductivity (at 0 ^oC)**	0.0288 W/mK	ASTM C518
Thermal resistance (at 0 ^oC)**	0.3035 m^{2}K/W	ASTM C518
	1.72 ft^2 ^oF. hr /BTU	
	4.37 ft^2 ^oF. hr /BTU.in	

MD/XD: Machine direction/ Cross machine direction
* Reflective layer property
** Insulating layer property
[1] Sample size 100 cm^2
[2] Modified for sample preparation before testing as per EN 13859-1 (2010) & EN 13859-2 (2010)
[3] Results based on multi-layer testing; 100%RH in the cup; 2.5 m/s air velocity above the cup; 30 min time interval
[4] Rate of use 60 cmH_2O/min

DuPont™ Tyvek® Cargo Covers

All technical information set out herein is provided free of charge and is based on technical data which DuPont believes to be reliable at the time of writing. Please verify that the properties given are suitable for your needs, as DuPont cannot accept liability for use under conditions outside our control, and users should verify that product is commercially available and fit for their purpose. This is a selection of cover specifications and may be subject to change without prior notice.

Tyvek® Cargo Covers are available in a range of sizes to fit the most frequently used pallet configurations. They are supplied as one piece top covers, but may also be used in combination with a separate bottom cover. Please ask regarding availability of specific cover sizes or any required print / branding options.

For further information on our products and services, please contact your account representative or visit: www.cargocovers.tyvek.co.uk.

Safety and Environmental considerations:

Tyvek® is non-toxic and chemically inert. Its strength and durability relative to its light-weight make it a resource efficient material compared to heavier and bulkier products.

Tyvek® Xtreme™ W50 Cargo Covers are made essentially of HDPE and polyester and should be disposed of according to local regulations. At the end of their lifecycle, they can be safely reprocessed as a polymer resin for other uses or alternatively incinerated for energy recovery.

Tyvek® end use temperatures should in all cases be under 90°C. Tyvek® melts at 135°C.

Storage considerations:

Keep away from flames.
Gloves recommended when handling.
Do not store the product in the vicinity of strong oxidizing agents.
For optimum shelf life, keep the product in its original packaging and adopt a best practice of first in first out (FIFO). It is recommended to use the covers within 2 years of supply to maintain highest efficiency.

Application considerations:

DuPont™ Tyvek® Cargo Covers are designed for one-time use or limited re-use, in line with sanitary regulations and pest management best practices in the transportation industry.

DuPont™ Tyvek® Cargo Covers are thermal covers so they should not be removed before arrival at the final destination.

While widely used for load stabilization, stretch wrap films should not be applied on the outside of DuPont™ Tyvek® Cargo Covers, and especially not over a substantial part of the cover surface as this may compromise the thermal protection of the load.

DuPont™ Tyvek® Cargo Covers

DuPont™ Tyvek® Cargo Covers must be properly secured to the ULD if exposed to strong winds or turbine drafts while on the airport ramp.

DuPont™ Tyvek® Cargo Covers are designed as secondary packaging and are not certified for use in direct contact with food.

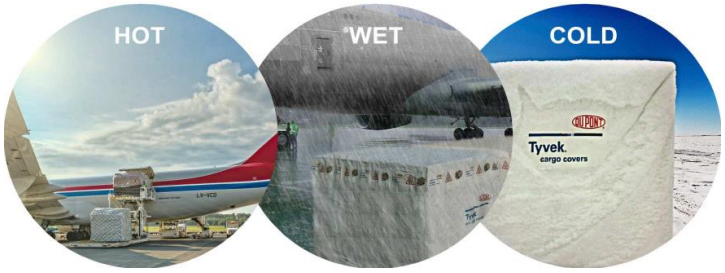
This datasheet is prepared with the best of our knowledge of the product and its ingredients. Should you have any question regarding end-use, processing, safety or environmental considerations please contact your DuPont representative.

Disclaimer:

It is the user's responsibility to determine the selection of the appropriate cover for the particular purpose and that their particular conditions of use present no health or safety hazards. Since conditions of product use are outside of our control, DuPont makes no warranties, express or implied, and assume no liability in connection with the use of this information. Nothing herein is to be taken as license to operate under, or a recommendation to infringe any patents or trademarks. DuPont is not liable for product damage during the use of the cover.

To maintain efficacy, DuPont™ Tyvek® Cargo Covers must be stored in the original package under dry, normal temperature conditions. New and used covers are expected to deteriorate if not properly protected from dust, heat and humidity.

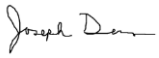
DuPont™ Tyvek® Cargo Covers have been intended for a one-time use to protect temperature sensitive products. Covers are to be considered as complementary to a user's established cold chain best practices, according to the Good Distribution Practice.



Europe: www.cargocovers.tyvek.co.uk
USA: www.cargocovers.dupont.com

TECHNICAL DATA & DOCUMENTATION

TEST DATA OF TYVEK® CARGO COVERS FOR PHARMACEUTICALS, PERISHABLES AND TEMPERATURE SENSITIVE PRODUCTS

Reviewed and approved by:	Alain Weimerskirch  Application Development Specialist	Date: 11 Aug 2016
Reviewed and approved by:	Joseph Dennes  Global Technology Manager	Date: 11 Aug 2016
Document number and name:	Technical_Data_&_Documentation_Tyvek®_ Solar™_W10_Cargo_Cover	
Version:	1.0	
Related documents:	n/a	

DuPont™ Tyvek® Solar™ W10 Cargo Cover

Tyvek® Solar™ W10 Cargo Covers provide outstanding protection to cargo when exposed to the sun during loading, transfer and unloading. This is the principal cause of temperature excursions during short-term breaks in the cold-chain. Affordable and easy to use, Tyvek® Solar™ W10 covers also offer inherent breathability in addition to all the other mechanical and hygienic benefits of low-conductivity Tyvek® material. By allowing the exchange of air and water vapour through the fabric, the covers help ensure that under-cover moisture levels do not reach damaging levels as a result of ambient temperature fluctuations.

Product data sheet

Property	Value	Test method
Basis weight[1]	58 ± 3 g/m^2	DIN EN ISO 536 (96)
Thickness[2]	170 ± 60 µm	DIN EN ISO 534 (05)
Tensile Strength[2]	MD 165 ± 25 N/5cm	EN 12311-1 (99)
	XD 140 ± 25 N/5cm	
Tensile Elongation[3]	MD 9 % ± 2 %	EN 12311-1 (99)
	XD 16.5 % ± 4.5 %	
Tear Resistance (nail shank)[3]	MD 65 ± 15 N	EN 12310-1 (99)
	XD 60 ± 15 N	
Emissivity	62.7 % ± 2 %	ASTM C1371
Light reflection (400 – 700 nm)	90.9 % ± 1.7 %	ASTM E1164
Moisture Vapor Transmission[4]	1675 ± 725 g/m^2/24h	DIN EN ISO 12572 C
Water pressure (Hydrostatic Head)[5]	>170 cm H_2O	DIN EN 20811 (92)
Resistance to penetration of water[3]	W1 PASS	DIN EN 1928-A (00)

MD/XD: Machine direction/ Cross machine direction
[1] Sample size 100 cm^2
[2] Surface 2 cm^2, pressure 100 kPa
[3] Modified for sample preparation before testing as per EN 13859-1 (2010) & EN 13859-2 (2010)
[4] Results based on multi-layer testing; 100%RH in the cup; 2.5 m/s air velocity above the cup; 30 min time interval
[5] Rate of use 60 cmH_2O/min

All technical information set out herein is provided free of charge and is based on technical data which DuPont believes to be reliable at the time of writing. Please verify that the properties given are suitable for your needs, as DuPont cannot accept liability for use under conditions outside our control, and users should verify that product is commercially available and fit for their purpose. This is a selection of cover specifications and may be subject to change without prior note.

DuPont™ Tyvek® Cargo Covers

Tyvek® Cargo Covers are available in a range of sizes to fit the most frequently used pallet configurations. They are supplied as one piece top covers, but may also be used in combination with a separate bottom cover. Please ask regarding availability of specific cover sizes or any required print / branding options.

For further information on our products and services, please contact your account representative or visit: www.cargocovers.tyvek.co.uk.

Safety and Environmental considerations:

Tyvek® is non-toxic and chemically inert. Its strength and durability relative to its light-weight make it a resource efficient material compared to heavier and bulkier products.

Tyvek® is made essentially of HDPE and should be disposed of according to local regulations. At the end of its lifecycle, it can be safely reprocessed as a polymer resin for other uses or alternatively incinerated for energy recovery.

Tyvek® end use temperatures should in all cases be under 90°C. Tyvek® melts at 135°C.

Tyvek® reaction to fire is that it substantially reduces flame spread according to ISO 3795 Horizontal measurement.

Storage considerations:
Keep away from flames.
Gloves recommended when handling.
Do not store the product in the vicinity of strong oxidizing agents.
For optimum shelf life, keep the product in its original packaging and adopt a best practice of first in first out (FIFO). It is recommended to use the covers within 2 years of supply to maintain highest efficiency.

Application considerations:
DuPont™ Tyvek® Cargo Covers are designed for one-time use or limited re-use, in line with sanitary regulations and pest management best practices in the transportation industry.

DuPont™ Tyvek® Cargo Covers are thermal covers so they should not be removed before arrival at the final destination.

While widely used for load stabilization, stretch wrap films should not be applied on the outside of DuPont™ Tyvek® Cargo Covers, and especially not over a substantial part of the cover surface as this may compromise the thermal protection of the load.

DuPont™ Tyvek® Cargo Covers must be properly secured to the ULD if exposed to strong winds or turbine drafts while on the airport ramp.

DuPont™ Tyvek® Cargo Covers are designed as secondary packaging and are not certified for use in direct contact with food.

This datasheet is prepared with the best of our knowledge of the product and its ingredients. Should you have any question regarding end-use, processing, safety or environmental considerations please contact your DuPont representative.

Disclaimer:

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To maintain efficacy, DuPont™ Tyvek® Cargo Covers must be stored in the original package under dry, normal temperature conditions. New and used covers are expected to deteriorate if not properly protected from dust, heat and humidity.

DuPont™ Tyvek® Cargo Covers have been intended for a one-time use to protect temperature sensitive products. Covers are to be considered as complementary to a user's established cold chain best practices, according to the Good Distribution Practice.

Europe: www.cargocovers.tyvek.co.uk
USA: www.cargocovers.dupont.com

PRODUCTS & SERVICES
Passive Temperature Protection Experts

Product Specification Sheet

Document Type:	Product Number:	Effective Date:	Revision
Product/Shipping Specification	69160091	August 22, 2017	0

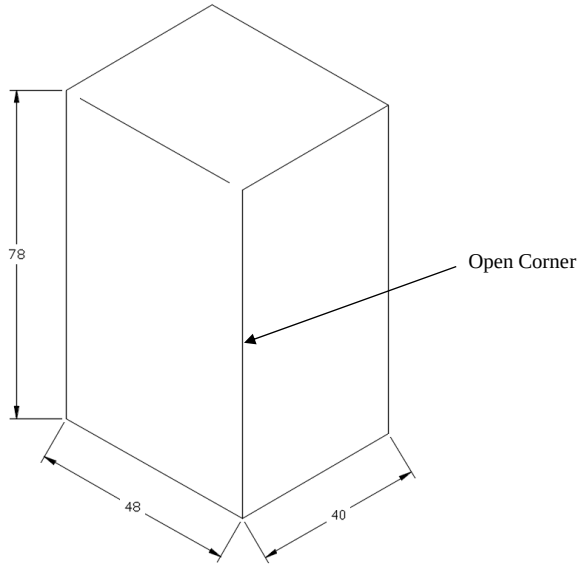
Product Name PFC, 40x48x78, One Corner Open

Product Description Light weight reflective air bubble insulation used to insulate skids of product. Designed to cover a payload of 40x48x78.

Product Features

1. Outer Substrate: Metalized polyester
2. Single layer of polyethylene bubble film
3. Inner Substrate: Clear Polyethylene
4. One corner open for slip over design
5. Nominal Thickness: 1/8”
6. Est. Wt. = 23 oz

Product Drawing



Shipping Contents

1. 69160091 – PFC 40x48x78, One Corner Open – 50 per box

Packaging Description

1. Skid size 48 inch x 48 inch
2. Carton, 48 x 48 x 36
3. Estimated Weight : 1 Box / Skid is 130 pounds or 2 Boxes / Skid is 185 pounds
4. Shipment Envelope : Min- 48x48x42 to Max- 48x48x80 (2 Boxes/Skid)

Shipping Classification H.T.C code 3921.13.5000

Approval	Date	Customer Signature	Date
Peter D Miabella	08/22/17		

PRODUCTS & SERVICES
Passive Temperature Protection Experts

Product Specification Sheet

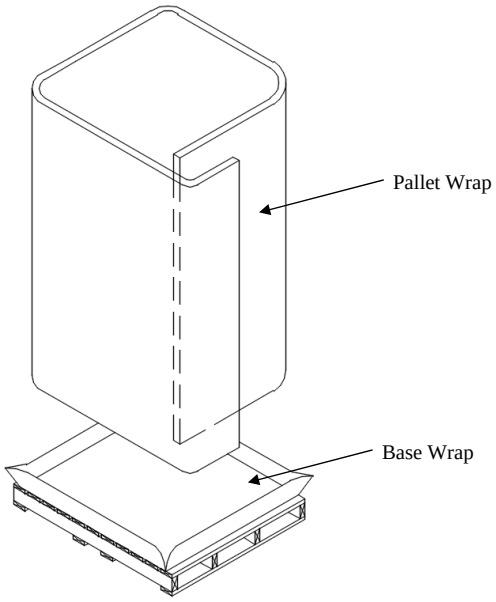
Document Type:	Product Number:	Effective Date:	Revision
Product/Shipping Specification	69000555	August 22, 2017	0

Product Name Pallet Wrap, 40x44x82

Product Description
Thermal Pallet Wrap used to protect all four sides and the bottom of a pallet of product measuring 40x44x82. The set includes a pallet wrap and base wrap.

Product Features
1. Outer lining is made of clear poly film
2. Standard loft insulation
3. Optional pallet bands to secure wrap closed
4. Est. Wt. = 21 lbs

Product Drawing



Shipping Contents
1. 69000555 – Pallet Wrap 40x44x82 – 4 per box

Packaging Description
1. Skid size 48 inch x 48 inch
2. Carton, 48 x 48 x 36
3. Estimated Weight : 1 Box / Skid is 160 pounds or 2 Boxes / Skid is 215 pounds
4. Shipment Envelope : Min- 48x48x42 to Max- 48x48x80 (2 Boxes/Skid)

Shipping Classification H.T.C code 3921.13.5000

Approval	Date	Customer Signature	Date
Peter D Miabella	08/22/17		