AIR TRANSPORT OF PERISHABLE PRODUCTS: A THERMAL ANALYSIS

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1 - INTRODUCTION

- Temperature is the most important factor in the postharvest life of horticultural products.

- Preserving the quality of fresh fruits and vegetables requires a proper cold chain from the field to the consumers' home.

- Transport operations are often responsible for breaks in the cold chain, particularly in the case of air shipments.

1 - INTRODUCTION

- Air transport plays a major role in the global food trade:
  - It provides a year-long supply of fresh produce
  - It allows the shipment of produce with short shelf-life

- Air transport of horticultural products:
  - Limited availability of temperature-controlled storage
  - Lack of knowledge
  - Variable conditions during ramp transfers and flights

1 - INTRODUCTION

Statement of the Problem:

- Studies focusing on temperature and air shipment of fresh fruit and vegetables are in limited number.

- Experimental data on in-flight conditions are particularly rare in the literature.

- Heat transfer in ULDs loaded with fresh produce has not been studied intensively.





2 - EXPERIMENTAL PROCEDURES

- Laboratory Tests

  Single-Box Tests
  Aircraft Container Tests

- Air Transport Tests





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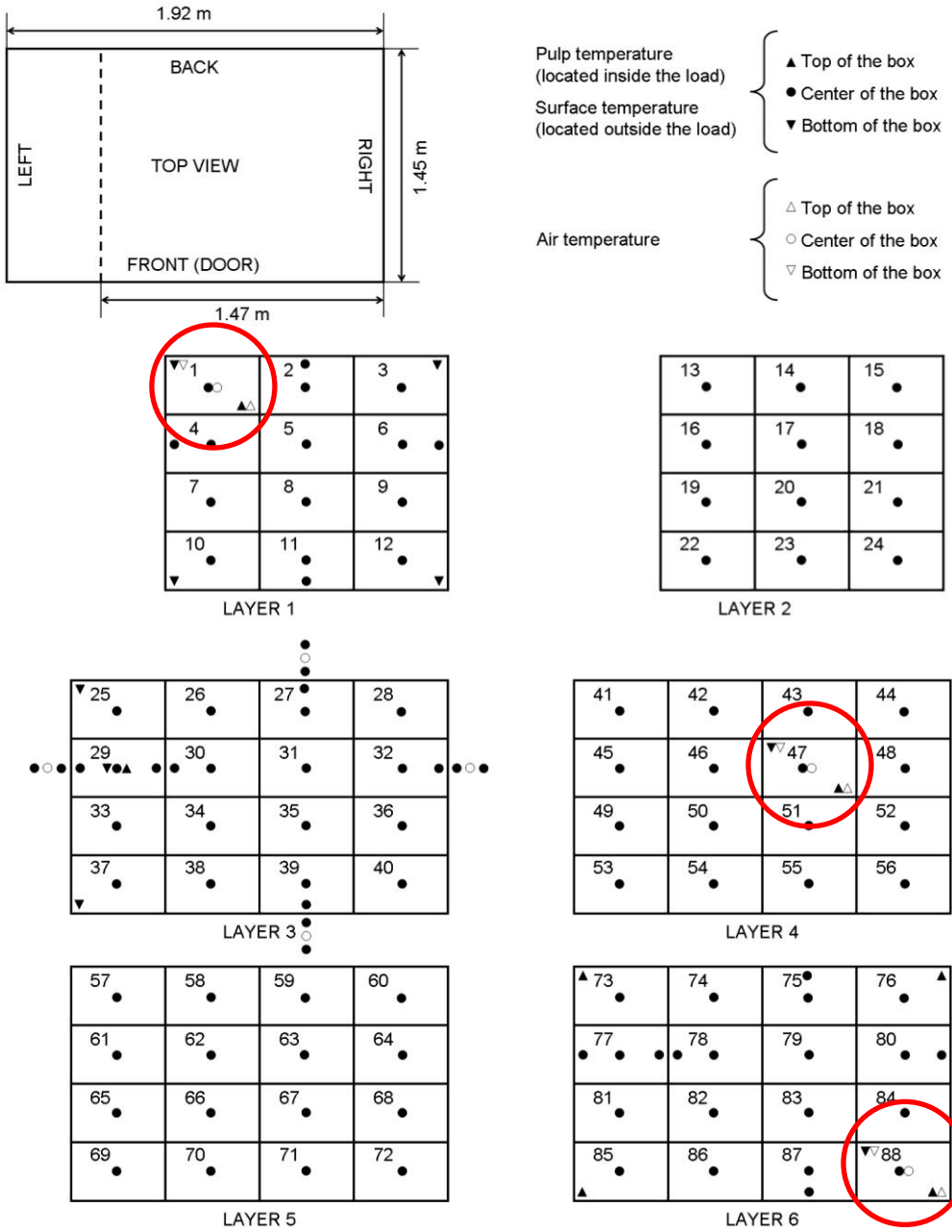


2 - EXPERIMENTAL PROCEDURES

Air Transport Tests

The objective was to gather in-flight pressure and temperature data in a fully loaded LD3 aircraft container.

Tests were conducted on six international flights.

Simulated products were used.





2 - EXPERIMENTAL PROCEDURES

Air Transport Tests

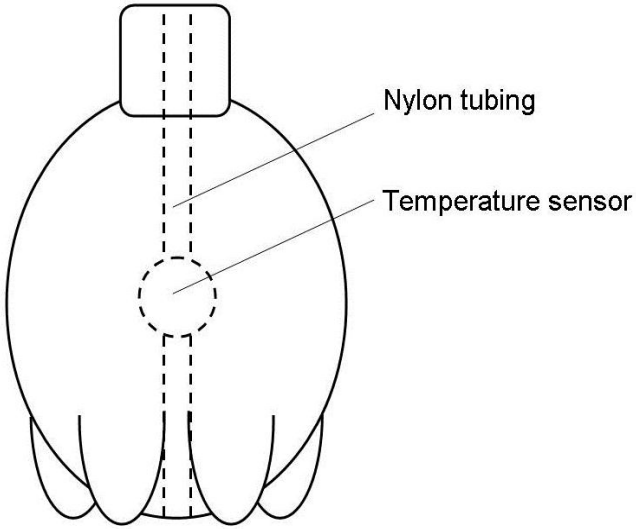
Simulated products in reusable plastic containers (RPCs)

- 50 RPCs
- 72 bottles/RPC

2 - EXPERIMENTAL PROCEDURES

Air Transport Tests

Instrumentation and temperature measurements



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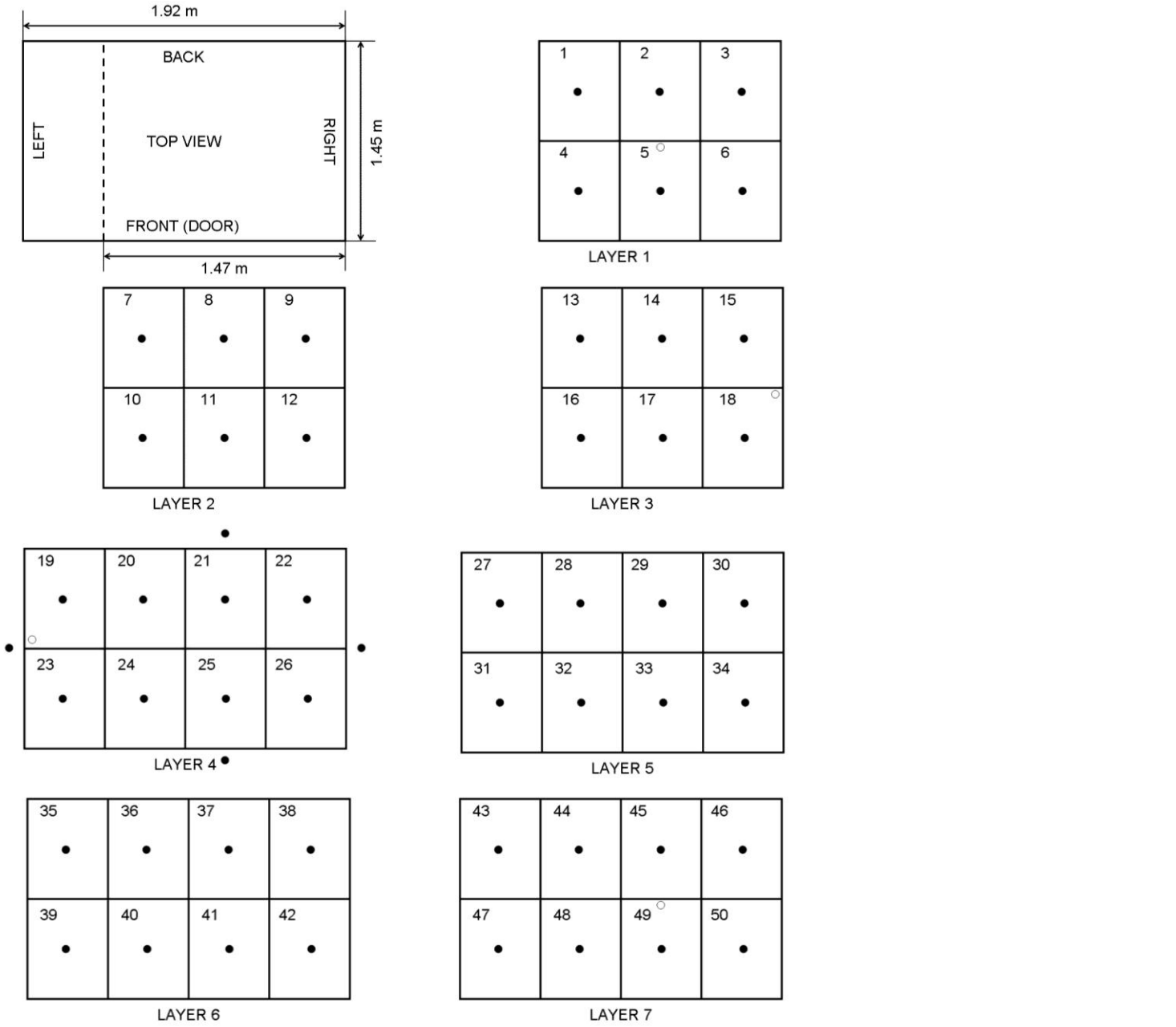


2 - EXPERIMENTAL PROCEDURES

Air Transport Tests

Flight	Date	Departure	Arrival	Duration	Aircraft	Position
JFK-GOT-DXB	04-29	11:00	*11:00*	16:00	B747-400F	44R
DXB-NBO	05-03	10:05	14:15	5:10	A330-200	41L
NBO-DXB	05-04	23:00	*5:00*	5:00	A310-300F	11L
DXB-NBO	05-06	10:05	14:15	5:10	A330-200	32R
NBO-DXB	05-07	17:15	23:15	5:00	A330-200	14L
DXB-GOT-JFK	05-12	23:00	*8:00*	17:00	B747-400F	43L

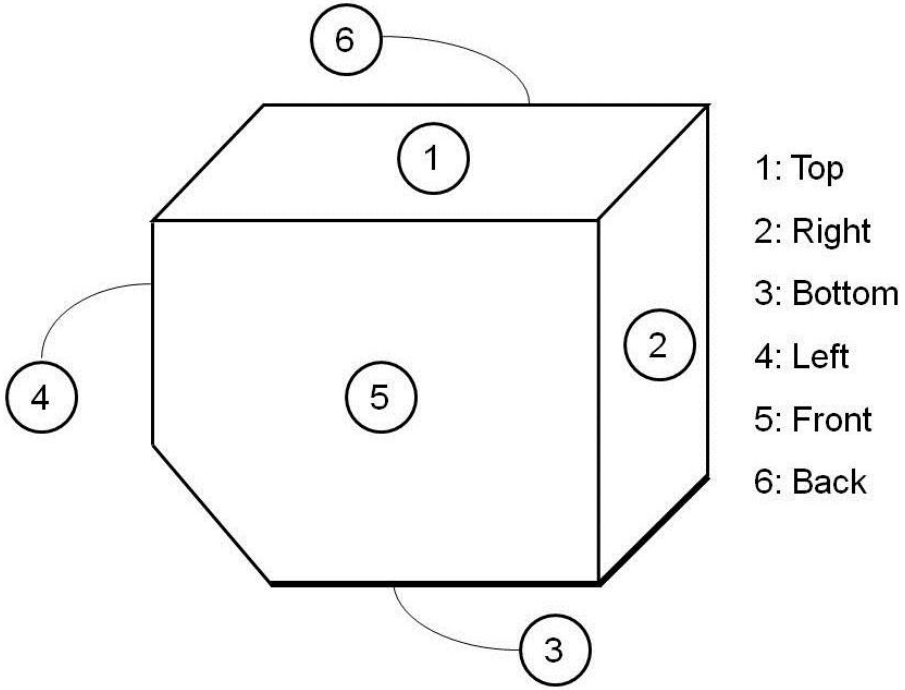




3 - RESULTS OF LABORATORY TESTS

3.1 Aircraft Container Tests

- Wall temperatures
- Average temperatures of the layers of boxes
- Temperatures of fruit located near the surface of the load



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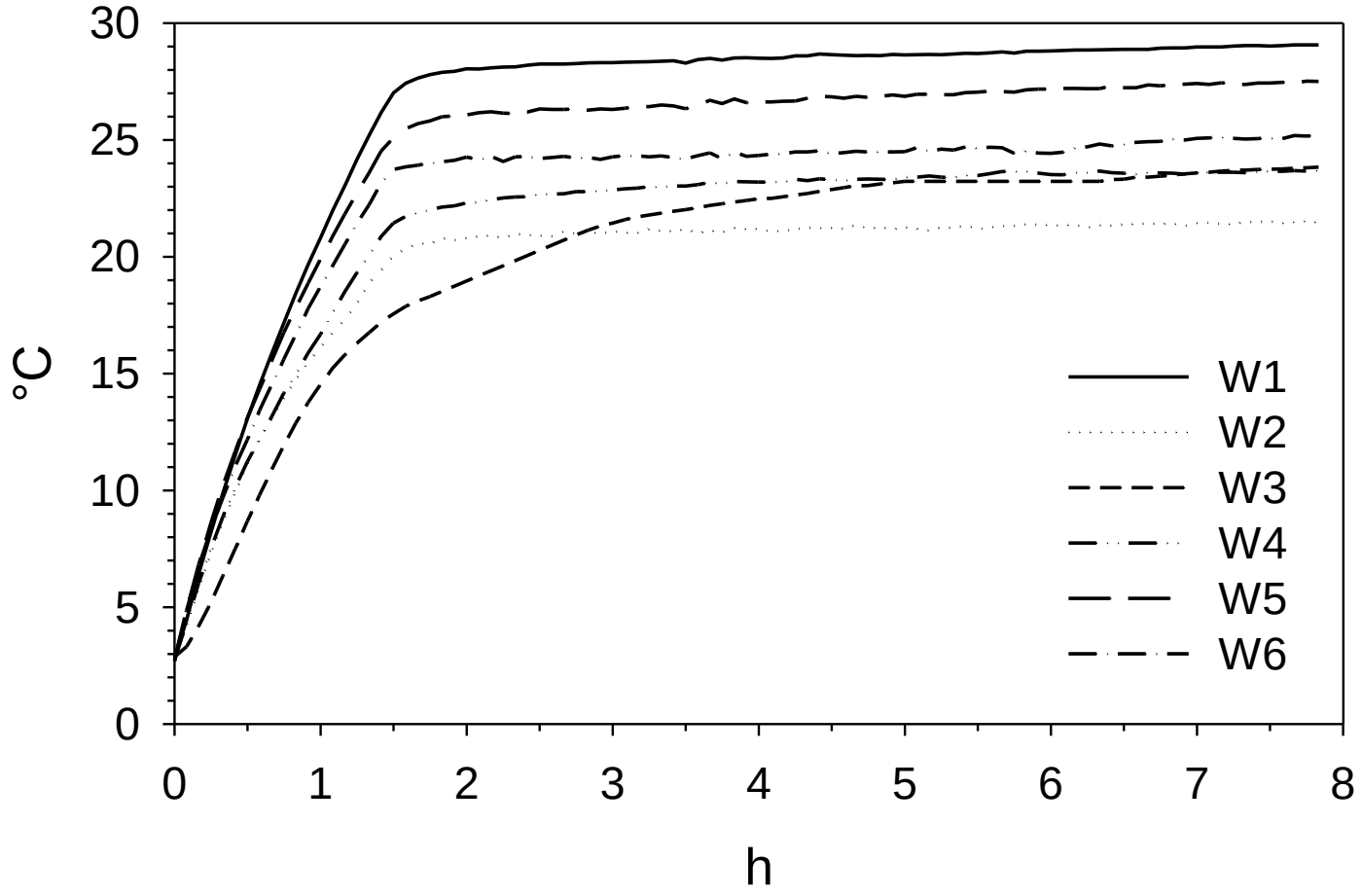

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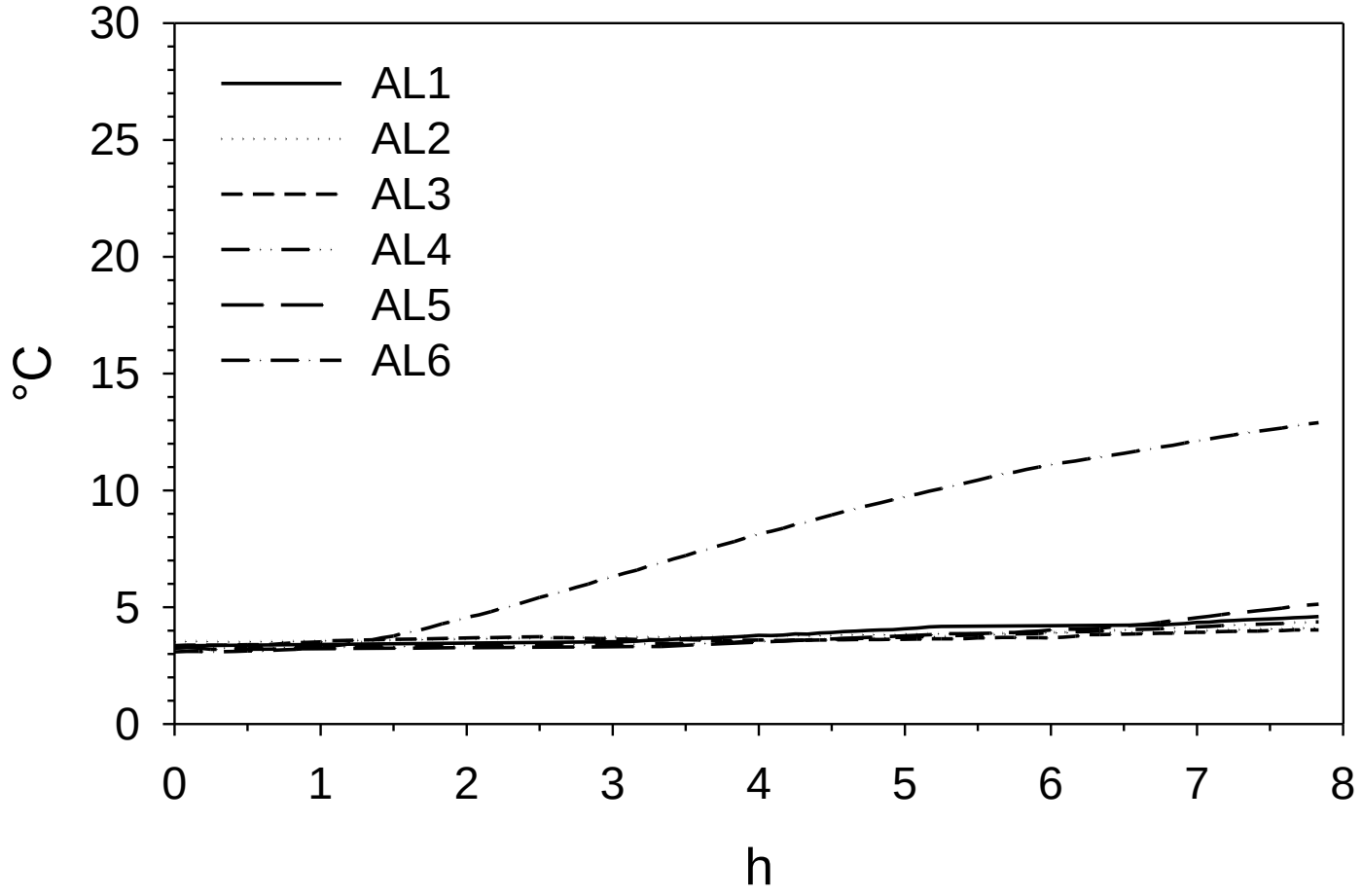

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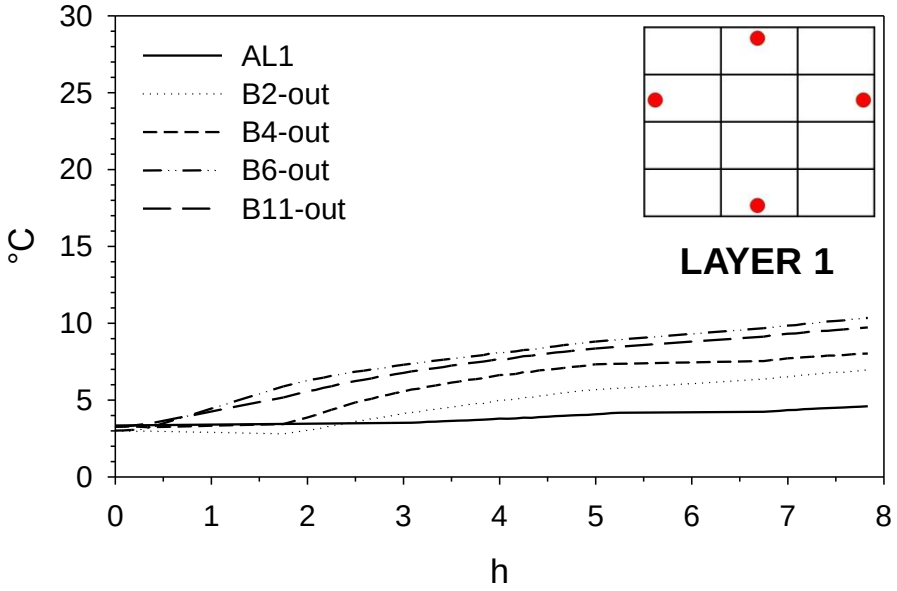
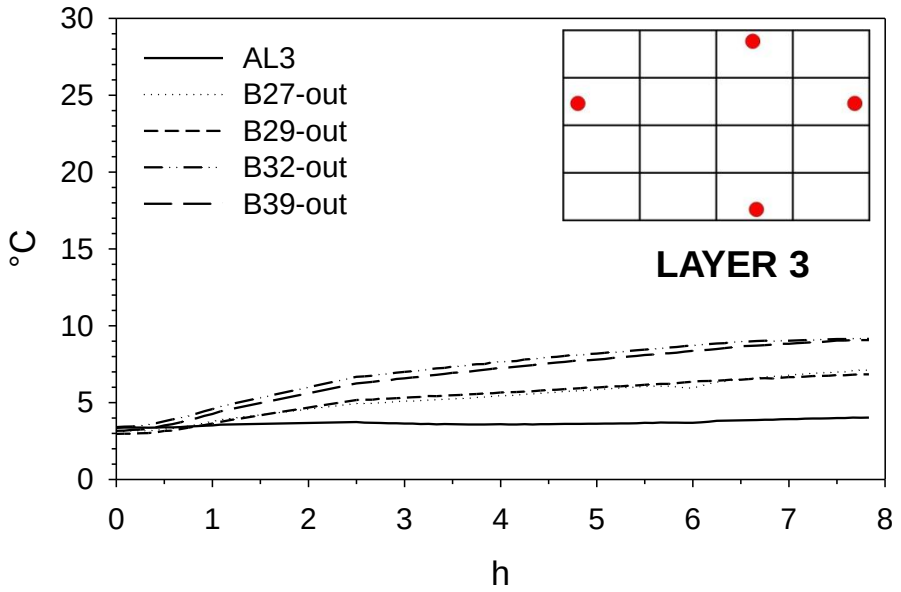
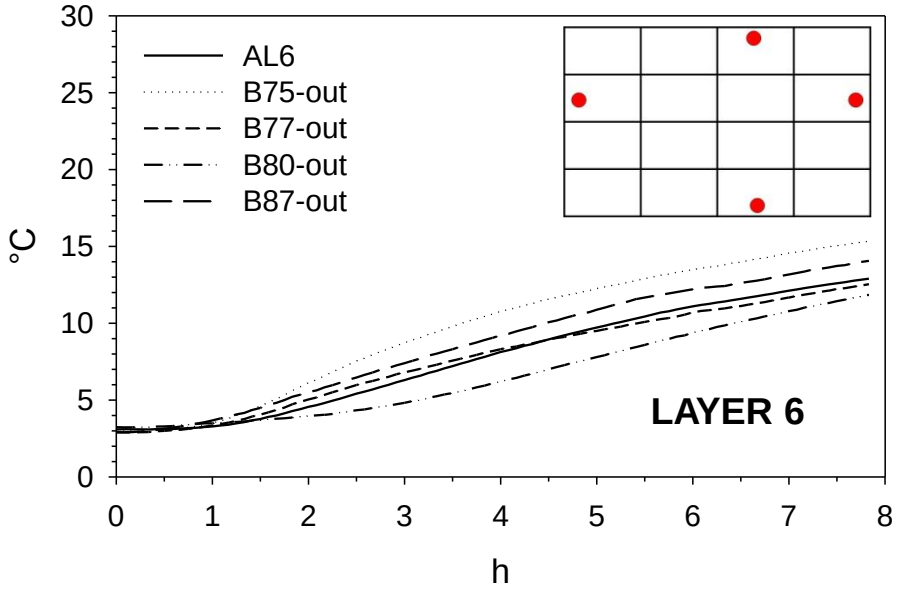






3 - RESULTS OF LABORATORY TESTS

3.1 Aircraft Container Tests

Conclusions

- With the exception of the top layer of boxes, the temperatures of the fruit located in the core of the load were not significantly affected.
- The fruit located in the peripheral region of the load, which accounted for 45.7% of all fruit, were affected.
- Except for the first layer, the temperature was vertically stratified within the load.

4 - RESULTS OF AIR TRANSPORT TESTS

There were six shipments completed through the following airports:

JFK: New York, U.S.A., John F. Kennedy International Airport

GOT: Landvetter, Sweden, Gothenburg-Landvetter Airport

DXB: Dubai, U.A.E., Dubai International Airport

NBO: Nairobi, Kenya, Jomo Kenyatta International Airport

Results of flight from JFK-GOT-DXB and DXB-NBO are presented.

4 - RESULTS OF AIR TRANSPORT TESTS

- Each shipment was divided in 3 sections:

  1) Container is outside on the tarmac during the ramp transfer prior to departure.

  2) Container is onboard the aircraft.

  3) Container is outside on the tarmac during the ramp transfer after arrival.

- The average temperatures of the layers and the temperatures of the walls of the aircraft container are presented.

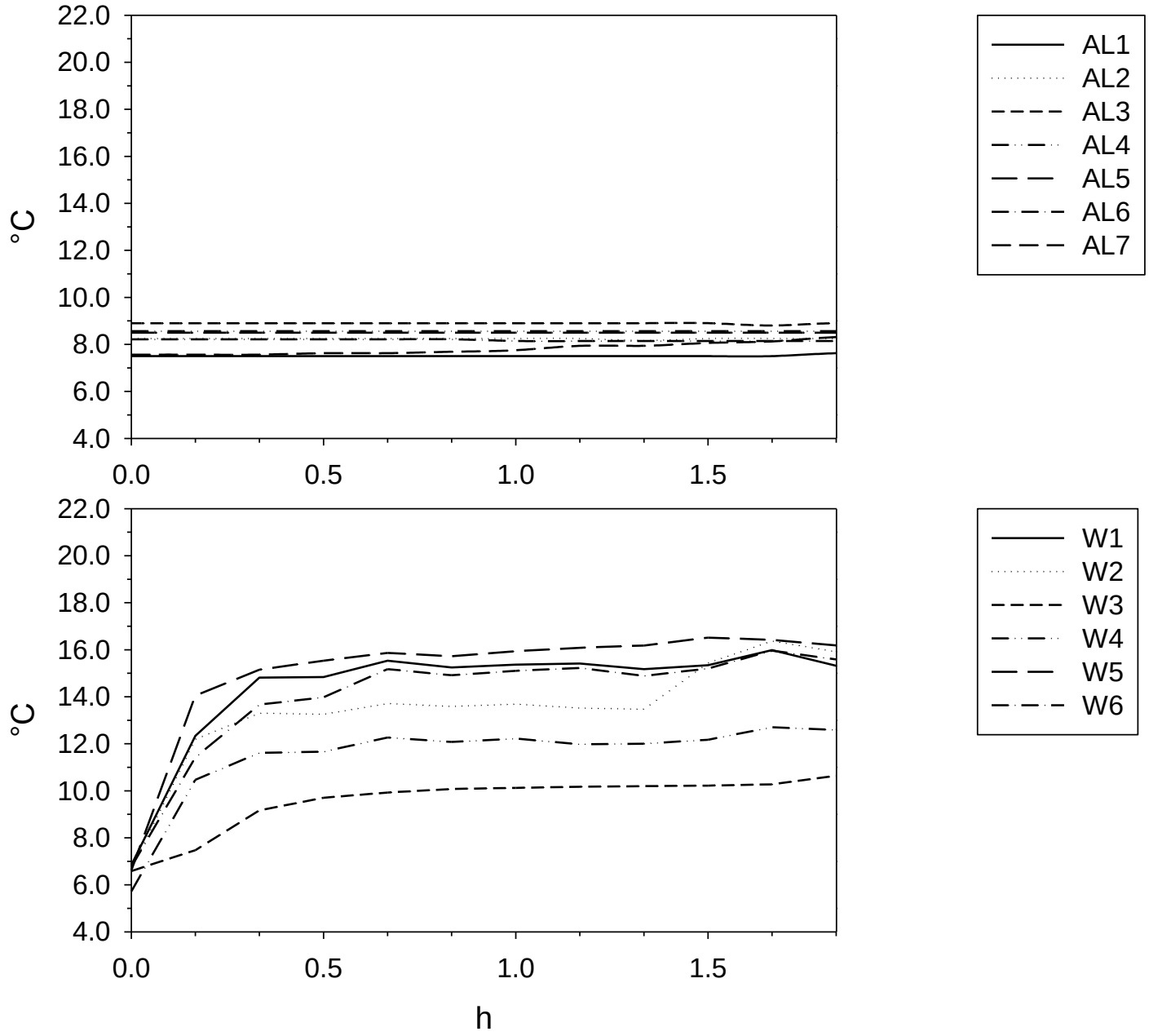
4 - RESULTS OF AIR TRANSPORT TESTS

4.1 JFK-GOT-DXB

Ramp Transfer at JFK Airport

- Container was taken out of refrigerated storage at 10:10.
- Ramp transfer of 1 h 50 min
- Overcast conditions
- Ambient temperature varied between 14.4°C and 16.1°C.

4 - RESULTS OF AIR TRANSPORT TESTS



4 - RESULTS OF AIR TRANSPORT TESTS

4.1 JFK-GOT-DXB

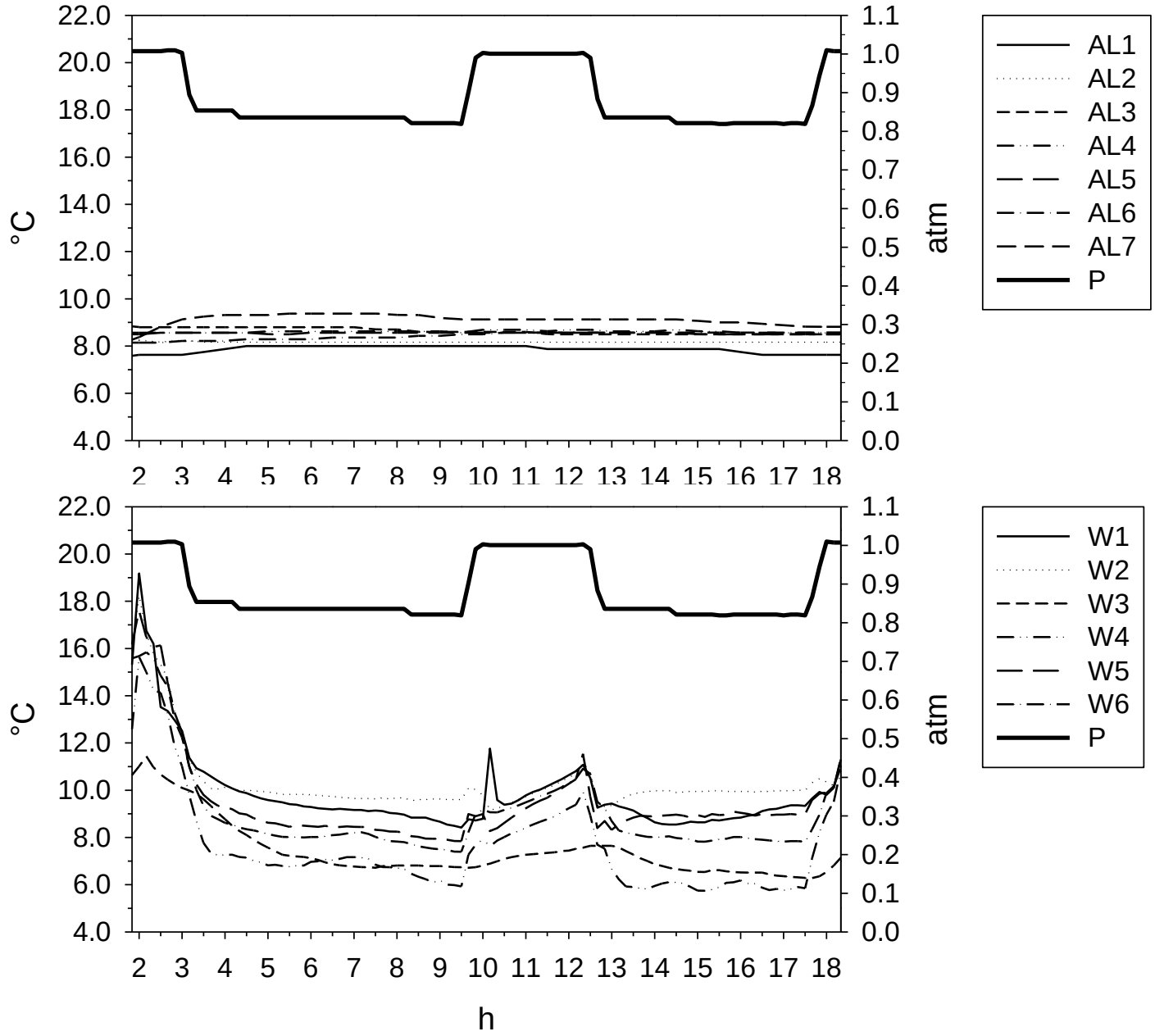
Onboard the Aircraft (B747-400F)

- The container was onboard for a period of 16 h 30 min.

- The temperature set-point of the cargo compartment was 10°C.

- Just prior to takeoff, the wall temperature of the container varied between 10.1°C and 12.5°C.

4 - RESULTS OF AIR TRANSPORT TESTS



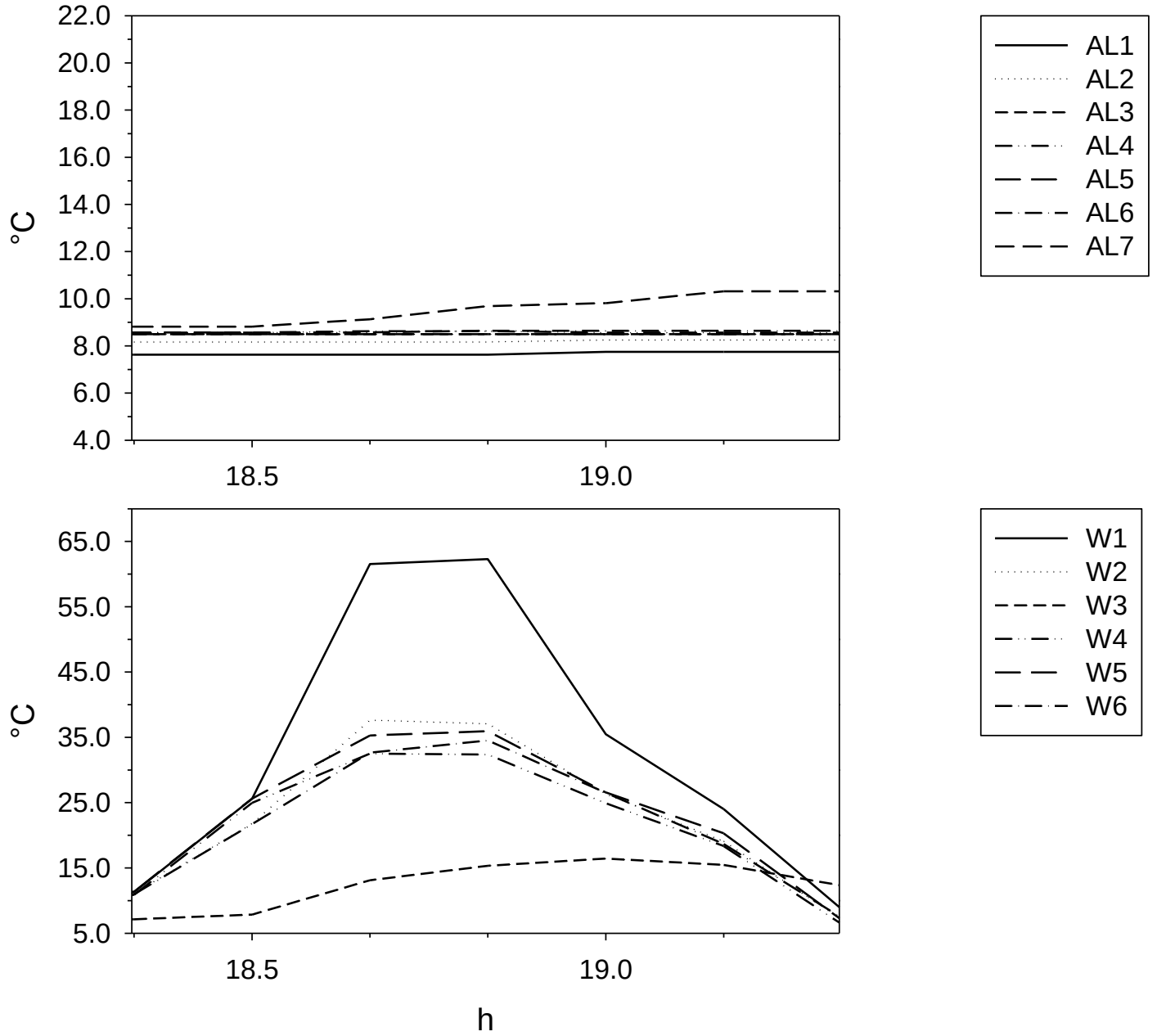
4 - RESULTS OF AIR TRANSPORT TESTS

4.1 JFK-GOT-DXB

Ramp Transfer at DXB Airport

- Aircraft container was unloaded at 12:30, 20 min after arrival.
- At 12:00 the ambient air temperature was 34°C.
- The aircraft container remained on the tarmac for 1 h and it was exposed to solar radiation for a period of approximately 30 min.

4 - RESULTS OF AIR TRANSPORT TESTS



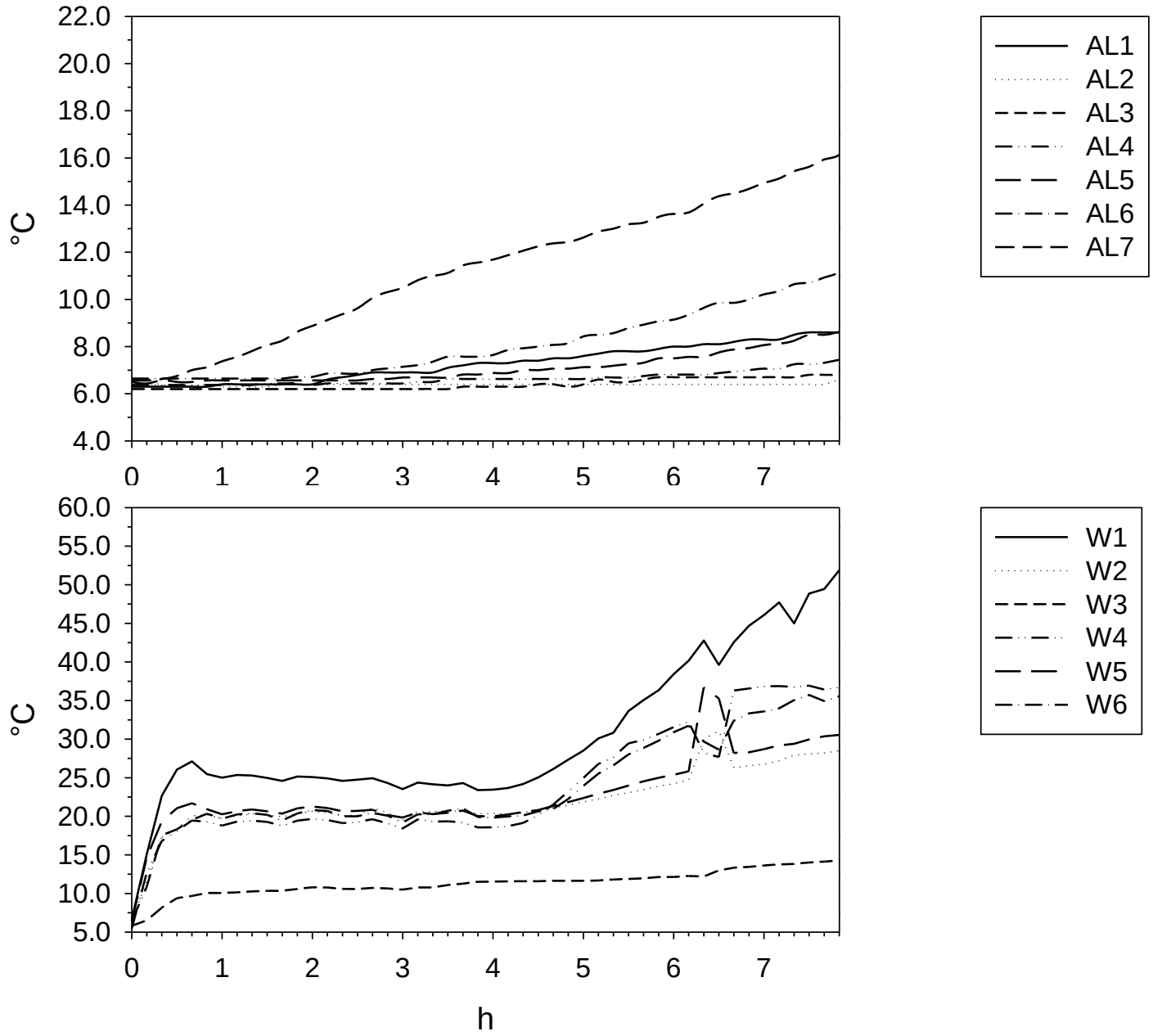
4 - RESULTS OF AIR TRANSPORT TESTS

4.2 First Shipment DXB-NBO

Ramp Transfer at DXB Airport

- The flight was schedule to depart from DXB airport at 10:05 and land at NBO airport at 14:15.
- At 1:40, 8 h 25 min prior to departure, the container was taken out of the cold room.
- At 2:00, the ambient air temperature was 29°C with clear-sky conditions.

4 - RESULTS OF AIR TRANSPORT TESTS



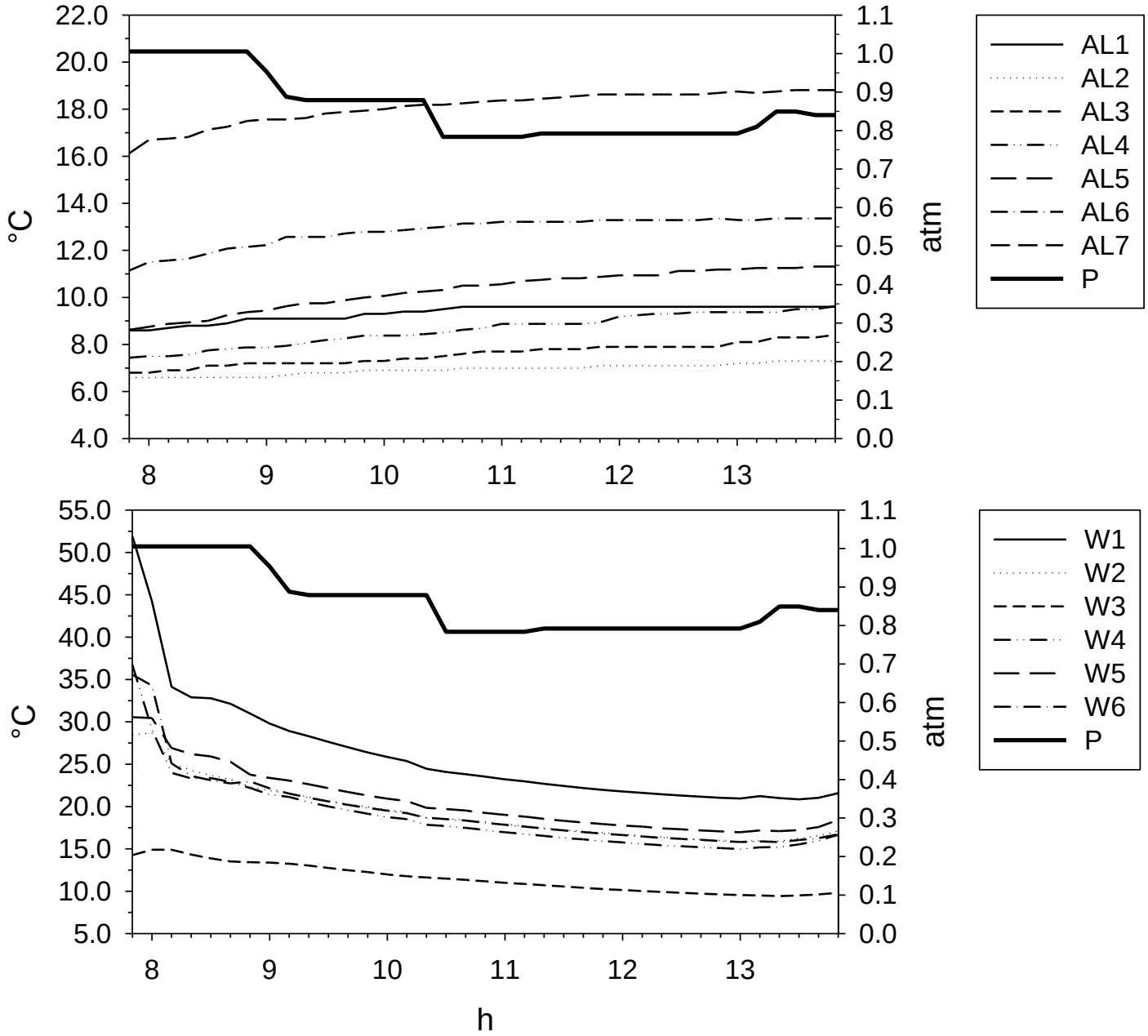
4 - RESULTS OF AIR TRANSPORT TESTS

4.2 First Shipment DXB-NBO

Onboard the Aircraft (A330-200)

- The aircraft container was onboard for a period of 6 h.
- During the flight, the ambient temperature within the cargo hold of the passenger plane was maintained around 20°C.

4 - RESULTS OF AIR TRANSPORT TESTS



4 - RESULTS OF AIR TRANSPORT TESTS

4.2 First Shipment DXB-NBO

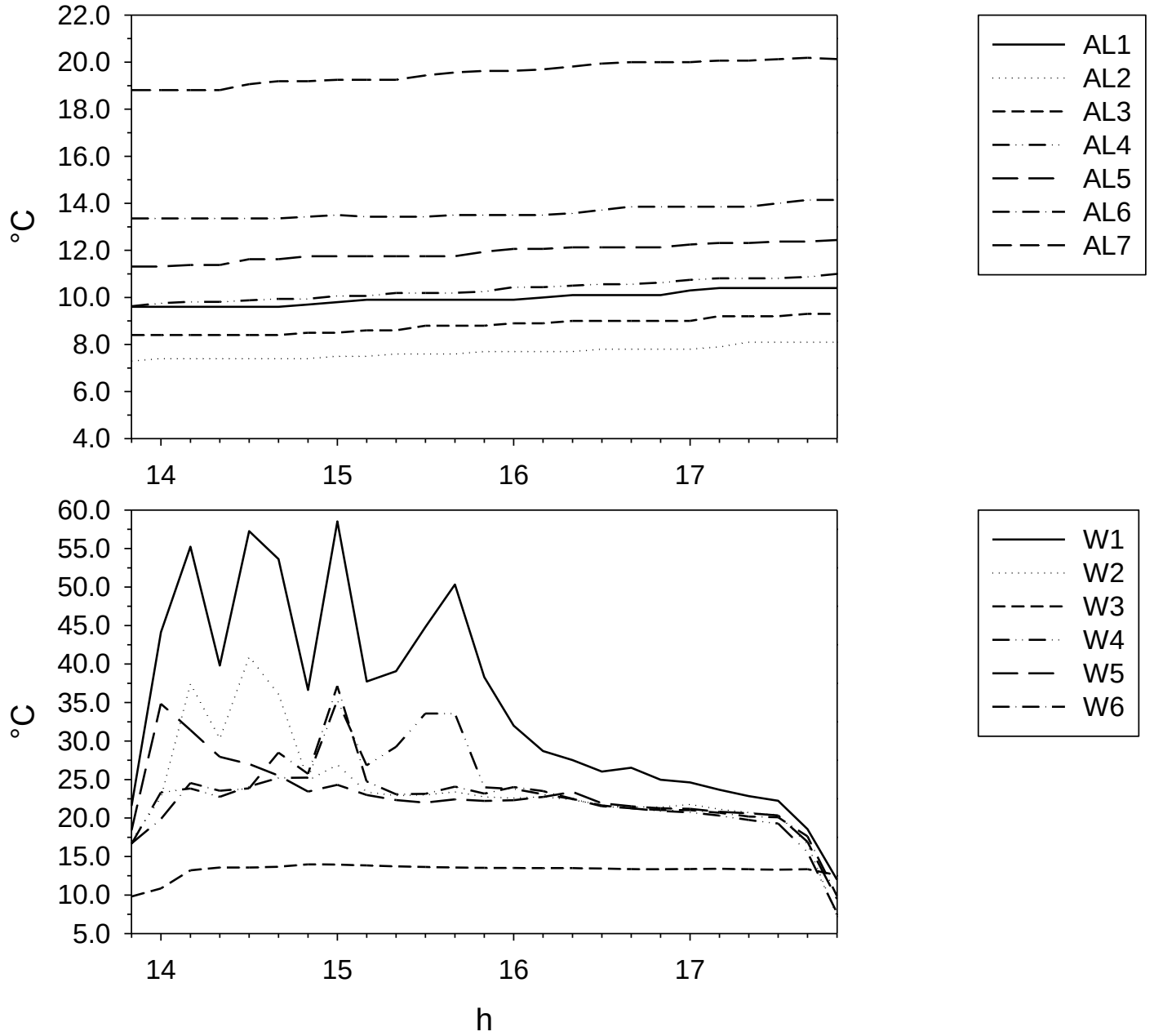
Ramp Transfer at NBO Airport

- At 14:00, the ambient temperature at NBO airport was 23.0°C with mostly cloudy conditions.

- Temperature of the top wall of the container peaked at four occasions within the first 2 h, reaching 58.3°C.

- For the last part of the ramp transfer, the conditions remained cloudy or the container was placed into a shady area.

4 - RESULTS OF AIR TRANSPORT TESTS



4 - RESULTS OF AIR TRANSPORT TESTS

4.4 Conclusions on Air Transport Tests

- ULDs can be exposed to ambient conditions for several hours during ramp transfers.

- Solar radiation can cause the temperatures of the walls of the aircraft container to increase significantly above that of ambient air.

- It is recommended that airlines used reflective breathable ULD covers to protect against solar radiation.

- Airports should also set up shaded areas on the ramp for temperature sensitive cargo.

4 - RESULTS OF AIR TRANSPORT TESTS

4.4 Conclusions on Air Transport Tests (continued)

- Environmental conditions during ramp transfers had a larger impact than in-flight conditions on the temperature distribution within the load of products.

- Initial temperature of the load is an important factor.





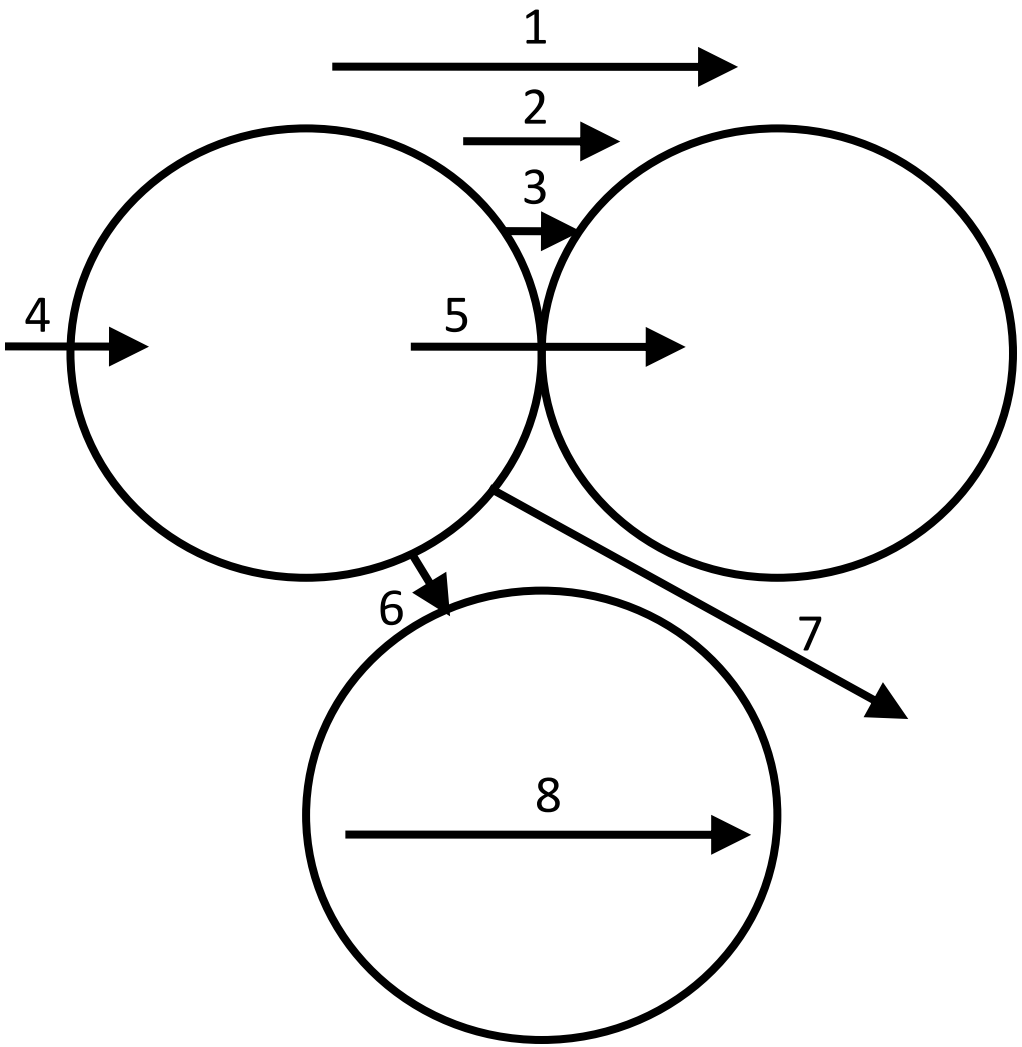
5 - EVALUATION OF HEAT TRANSFER MODELS BASED ON AN EFFECTIVE THERMAL CONDUCTIVITY

- For practical application in the transport industry, the approach used to predict the temperature within a load of horticultural products must be simple and efficient.

- The selected approach should be based on:
    - The thermal properties of the load
    - Its initial temperature
    - The variations with time of the temperatures at the boundaries of the domain.

- An effective property model is an interesting option.

5 - EVALUATION OF HEAT TRANSFER MODELS BASED ON AN EFFECTIVE THERMAL CONDUCTIVITY



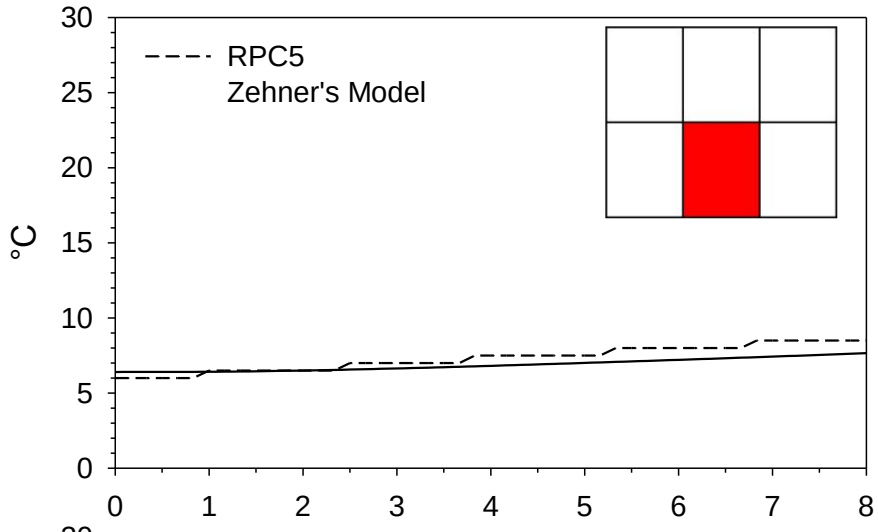
1) Convection in fluid
2) Conduction in fluid
3) Conduction in fluid film near contact point
4) Fluid-solid or solid-fluid heat transfer
5) Conduction through contact surface
6) Radiation between adjacent solids
7) Radiation between solids separated by more than a void space
8) Conduction through solid

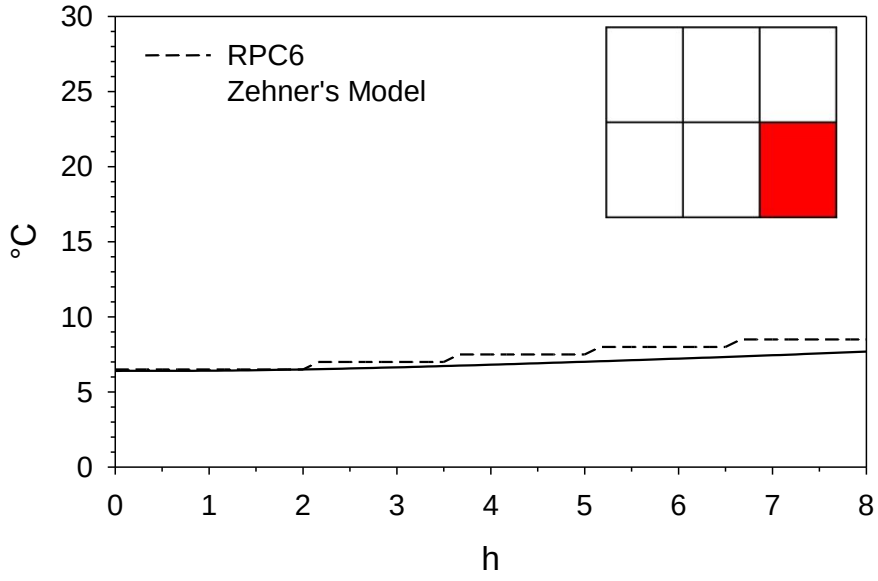
5 - EVALUATION OF HEAT TRANSFER MODELS BASED ON AN EFFECTIVE THERMAL CONDUCTIVITY

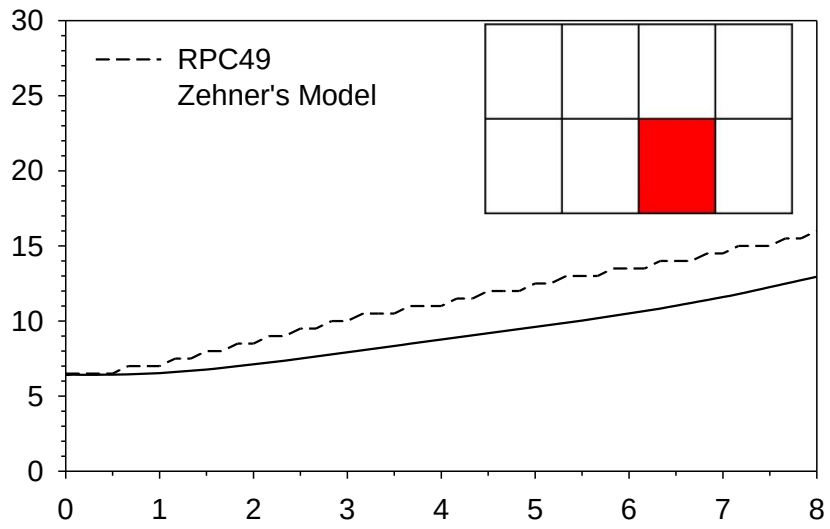
Simulation Results for Aircraft Container Tests

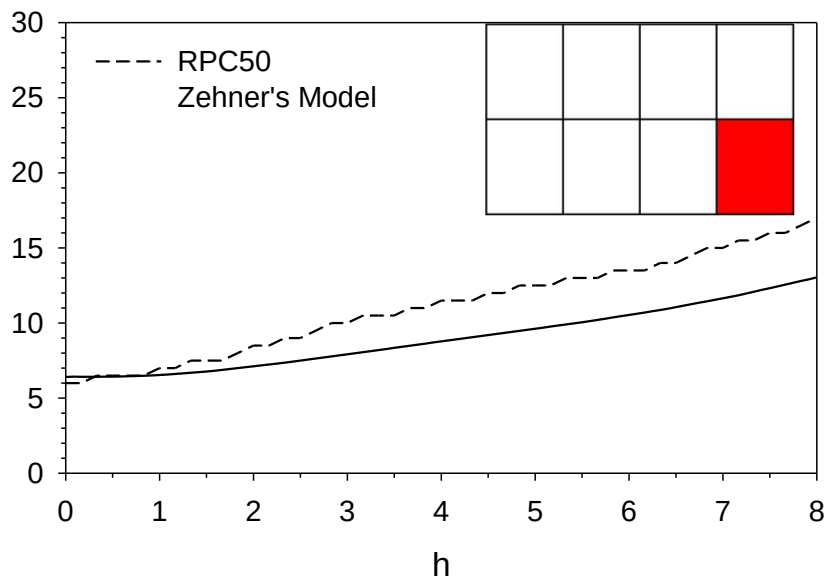
Air Transport Tests:

- An extended ramp transfer at DXB airport was simulated.
- The simulation provided good data for most of the load but underestimated the temperatures within the top layer of products.









LAYER 1

LAYER 7

5 - EVALUATION OF HEAT TRANSFER MODELS BASED ON AN EFFECTIVE THERMAL CONDUCTIVITY

5.3 Conclusions on the Modeling Approach

- In general, the model based on a static effective thermal conductivity needs to be improved to adequately predict the temperatures throughout loads of horticultural products.

- A dynamic component must be added to the effective thermal conductivity.

5 - EVALUATION OF HEAT TRANSFER MODELS BASED ON AN EFFECTIVE THERMAL CONDUCTIVITY

5.3 Conclusions on the Modeling Approach (continued)

- Better results are expected for smaller size products such as berries.

- The modeling approach did provide good predictions for the temperature of peripheral products, which account for approximately 50% of the all products within the ULD and are the most susceptible to temperature abuse.

- From that perspective, the modeling approach used can still be a useful tool for air shipments of perishable products.

THANK YOU - QUESTIONS

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