SEA FISH INDUSTRY AUTHORITY

Seafish Technology

SEAFISH

Cooling of Cooked and Smoked Fish in Retail Displays Report on Laboratory Trials

Internal Report No.1424

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Summary

From April 1993 Retailers will find it difficult to comply with the Food Hygiene (Amendment) Regulations which will require mongers to keep cooked and smoked fish products at or below 5°C. These products cannot be directly iced because of the adverse effect on appearance and texture. This work was carried out with the aim of developing a simple, inexpensive storage and display system for these products in a retail environment, applicable to both shops and retail vans.

Using ice as an indirect coolant, simple techniques were assessed for their ability to retain hot smoked mackerel fillets in trays below 5°C for 6 hours. The effect of re-icing, tray depth, air movement and various trays covers on fillet temperatures was assessed.

Several conclusions can be drawn from the work which was confirmed to laboratory tests:-

1. The use of stainless steel trays in a bed of crushed melting ice can achieve the desired product temperature.

2. Melted ice should be replaced at frequent intervals around trays to ensure maximum cooling effect is transferred to the fillet.

3. Fillets should be shielded from air movement by screens or covers.

4. Covers can be used in conjunction with tray re-icing and good practice to hold fillets at or below 5°C for over 6 hours.

The report gives details of the six experiments and makes provisional recommendations. The next stage is to design and build a prototype unit for use in shops and retail vans.

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1. Introduction

From April 1993 the Food Hygiene (Amendment) Regulations S.I. No. 1431 will demand that cooked and smoked fish products are stored and displayed at 5°C or below. The new legislation will result in many retailers being unable to meet legal requirements with existing equipment and techniques. Results obtained in previous Seafish studies on mobile and static retailers showed product temperature to be widely available and highly influenced by ambient temperatures. As smoked or cooked products are rarely suited to direct icing the aim of the trial was to find simple methods to keep products below 5°C.

The trials were carried out in the Seafish Laboratory in Hull, using an experimental test rig in order to explore all possible influences on temperature control.

At this stage firm conclusions can be drawn and recommendations made but it will be necessary to build a prototype unit for in service commercial trials.

2. Trials Sequence

Experiments were carried out using an insulated test bed containing ice, in which stainless steel trays containing hot smoked mackerel fillets were embedded. The basic equipment was designed to simulate the conditions found in a retail display environment.

The trial consisted of a progressive series of experiments.

The following were investigated:-

Experiment I The effect on fillet temperature of re-icing around trays.

Experiment II The effect on fillet temperature of tray depth.

Experiment III The effect on fillet temperature of air movement.

Experiment IV The effect on fillet temperature of an individual tray cover.

Experiment V The effect on fillet temperature of an overall cover.

Experiment VI The effect of a fan within the overall cover to circulate chilled air.

3. Trial Equipment and Common Experimental Method

The insulated test bed (*figure 1*) was constructed from 15mm hardboard coated with fibre glass and a 20mm outer layer of polystyrene. Overall dimensions were 1260mm x 955mm x 165mm with a 10mm drain hole. The bed was filled with crushed ice allowing trays containing fillets to be embedded in it to a maximum depth of 150mm.

Experimental work was carried out in the Seafish Laboratory between January and March 1992. To ensure stable ambient conditions the windows were covered with heavy brown paper to prevent direct sunlight and the heating system checked for fluctuations. The test bed was designed to allow controlled experiments to be carried out in a simulated retail/display environment.

In all experiments hot smoked mackerel fillets pre-conditions to 0°C were placed in pressed stainless steel trays 265mm x 330mm with depths ranging from 20mm to 150mm. The trays were embedded in crushed ice up to the lip. Type 'T' thermocouples connected to a Squirrel™ data logger were used to record core fillet temperature.

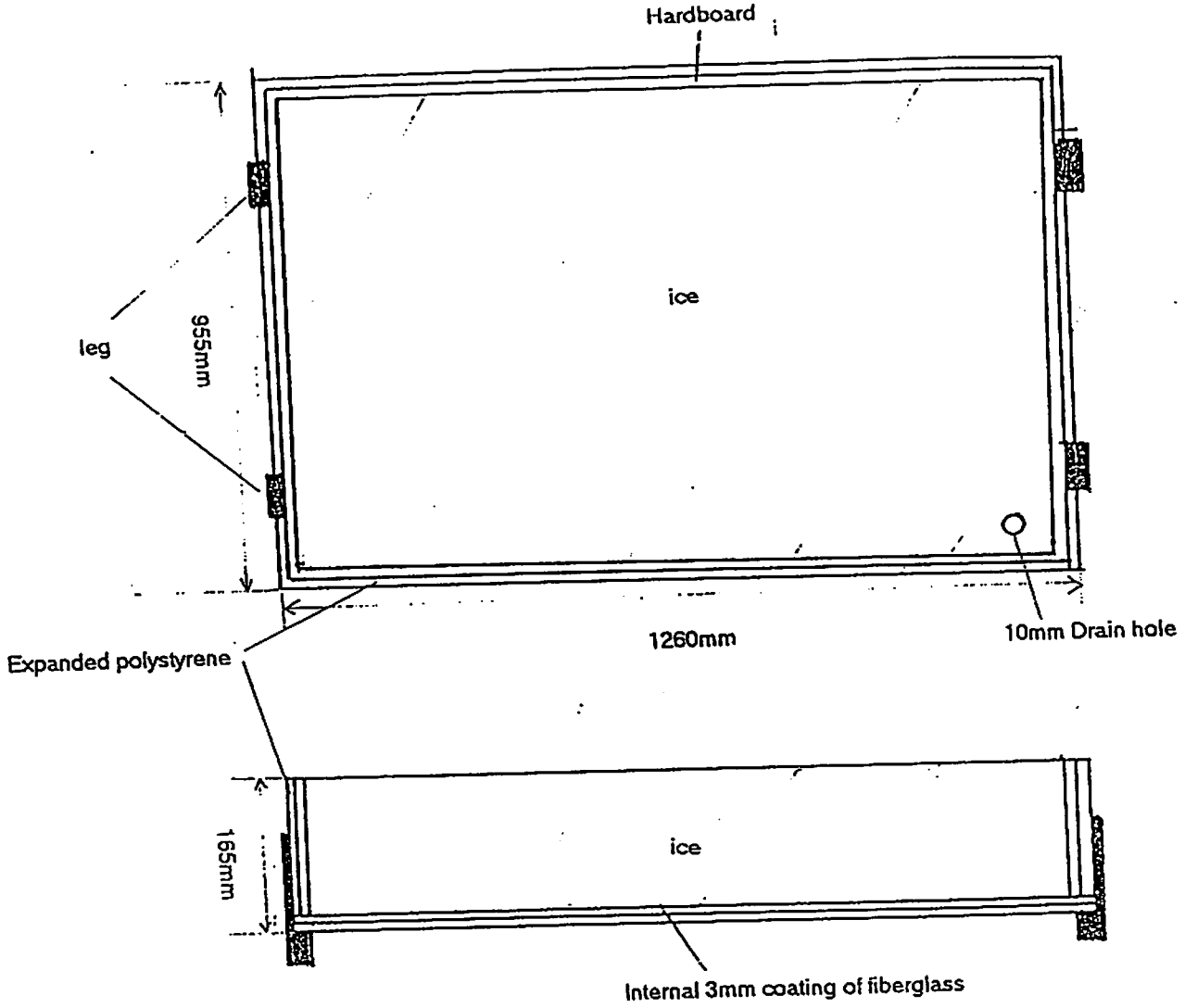


Diagram of the Insulated Test Bed. Figure 1.

4. Experiment I - The Effect of Re-icing

4.1 Introduction

The aim of this experiment was to compare the temperature of fillets stored in a 60mm deep tray around which ice was allowed to melt; with a tray which was periodically re-iced around its periphery to maintain contact between the sides of the tray and the ice.

4.2 Method

Two 60mm trays were embedded in crushed ice scraped level with the tray. Fillets were placed in each tray to a height of 40mm above ice level (*figure 2*). Data logger probes were inserted into the central stack of fillets at 40mm, 20mm and 0mm above ice level and (200mm), (40mm) and (60mm) below the level of ice. Ice melting from a 10cm zone around tray 1 was replaced hourly with fresh ice scraped level with the tray surface. The ice surrounding tray 2 was allowed to melt and was not replaced. Fillet temperatures and ambient temperatures (300mm above ice level) were recorded every 15 minutes over a 6 hour period.

4.3 Results

An average ambient temperature of 21.6°C was recorded.

During a 6 hour period ice melt was significant from around tray 2, which was not re-iced. The ice level fell to 50mm below the original level and up to 20mm away from the tray sides. A low level of melt was observed directly under the tray.

Data is shown graphically in *figure 3* and summarised in Table 1.

Fillets stacked in re-iced tray 1 were significantly colder than fillets in tray 2 which were not re-iced.

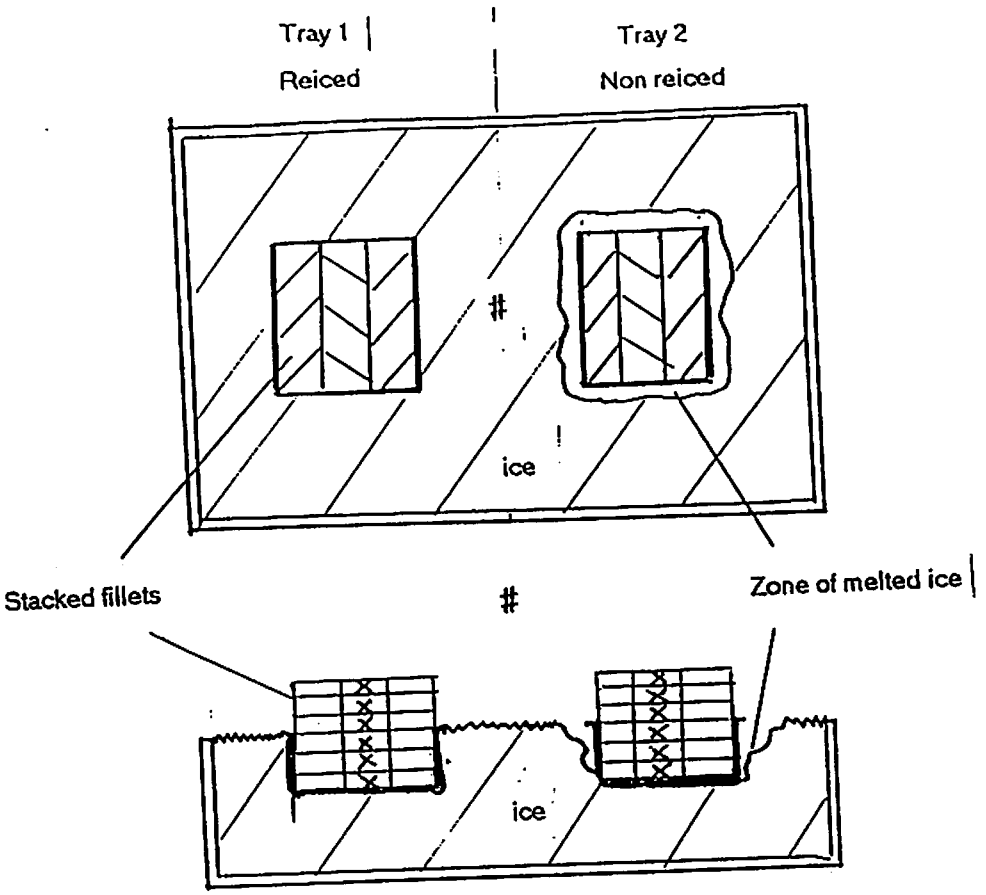
In the re-iced tray, fillets level with or above the ice were found to reach a temperature greater than 5°C after 6 hours. Fillets below ice level remained below 5°C.

In the non re-iced tray on fillets at 40mm below ice level or below remained under 5°C.

Table 1 - Experiment I
Fillet Temperature (°C) for re-iced and non re-iced trays after 6 hours

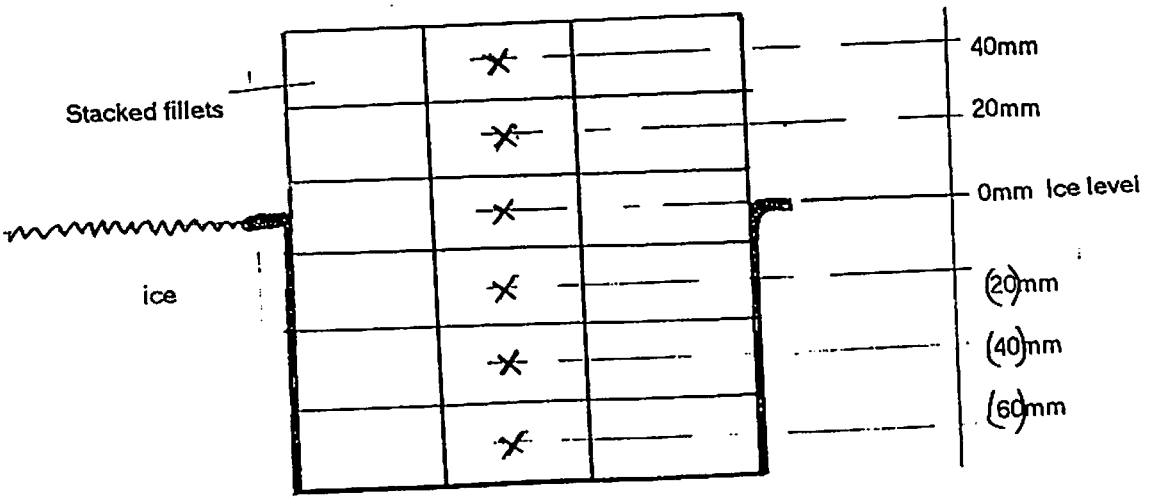
Fillet Height above/(below) tray level (mm)	Fillet Temperature (°C)		Difference in fillet temperature °C
	Tray 1 (re-iced)	Tray 2	
40	10.0	13.0	-3.0
20	7.8	11.0	-3.2
0	5.9	7.8	-1.9
(20)	4.0	5.6	-1.6
(40)	2.7	3.9	-1.2
(60)	0.9	1.0	-0.1

= Position of ambient temperature probe 300mm above ice surface.



Exploded view of fillet stacking

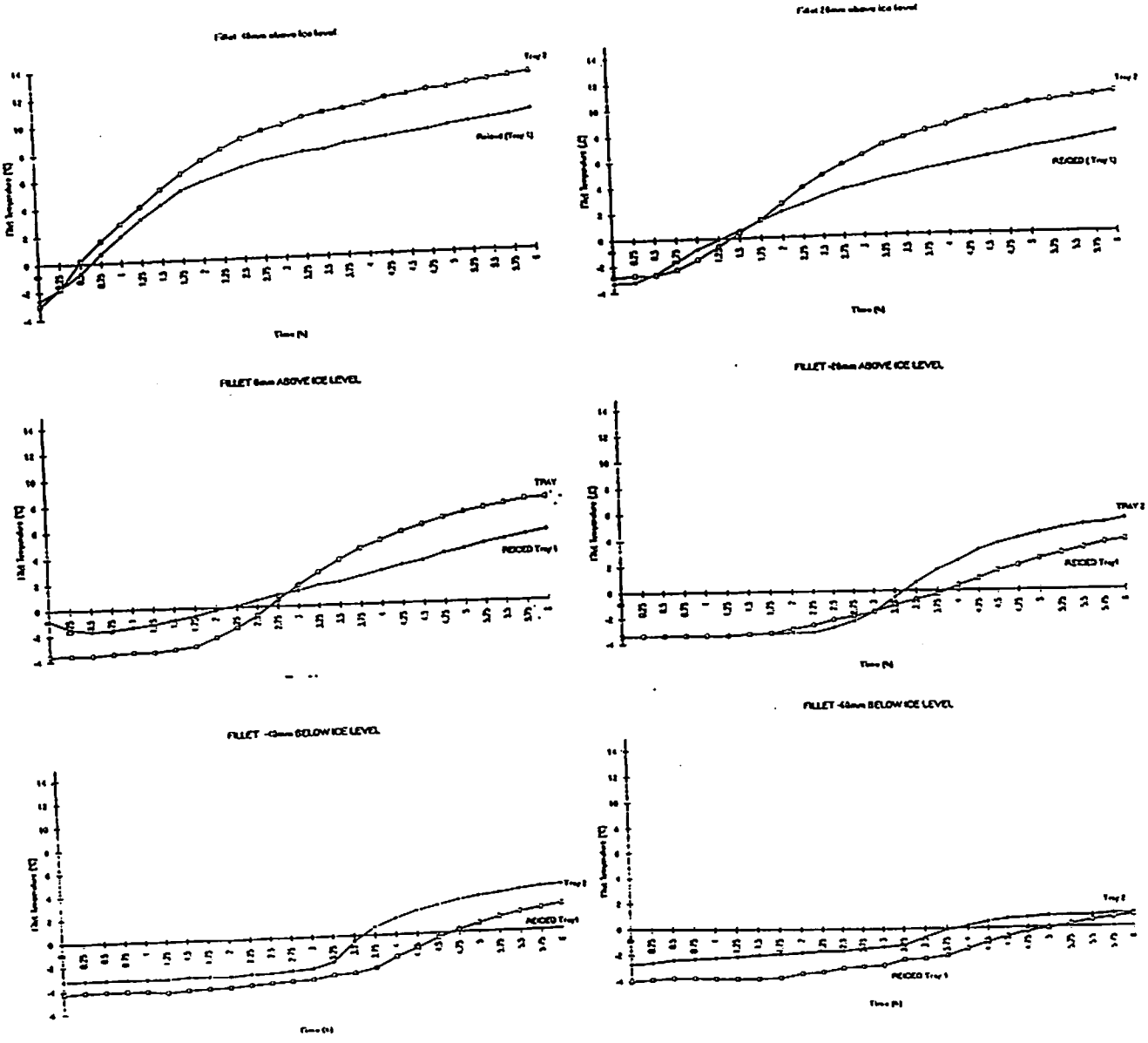
× = Location of temperature probe



Experiment I

Diagram of Fillet Stacking in Reicied and Non Reiced Trays. Figure 2.

AVERAGE AMBIENT TEMPERATURE 21.6°C



Experiment I

Graphs to show the effect of tray reicing on fillet temperature (°C)

Figure 3.

5. Experiment II - The Effect of Tray Depth on Fillet Temperature

5.1 Introduction

From the results of the re-icing experiment it appeared the fillets above ice level were vulnerable to rapid warming, in particular the fillet on top of the stack.

In this trial fillets were stacked above and below ice level inn trays of different depth to determine if the exposed top fillets could be maintained below 5°C for 6 hours. As re-icing had been found to significantly lower fillet temperature all trays were re-iced.

5.2 Method

Trays of depth 20mm, 60mm, 100mm and 150mm were embedded in the ice bed. Fillets were stacked to a height of 20mm, (20mm) (60mm) and (100mm), relative to ice level (*figure 4*).

Temperatures of top fillets and one fillet directly below were recorded. Re-icing was carried out on all trays every 60 minutes. Fillet temperature and air temperature 300mm above ice level was recorded over a 6 hour period.

5.3 Results

The average ambient temperature 30cm above ice level was 21.5°C.

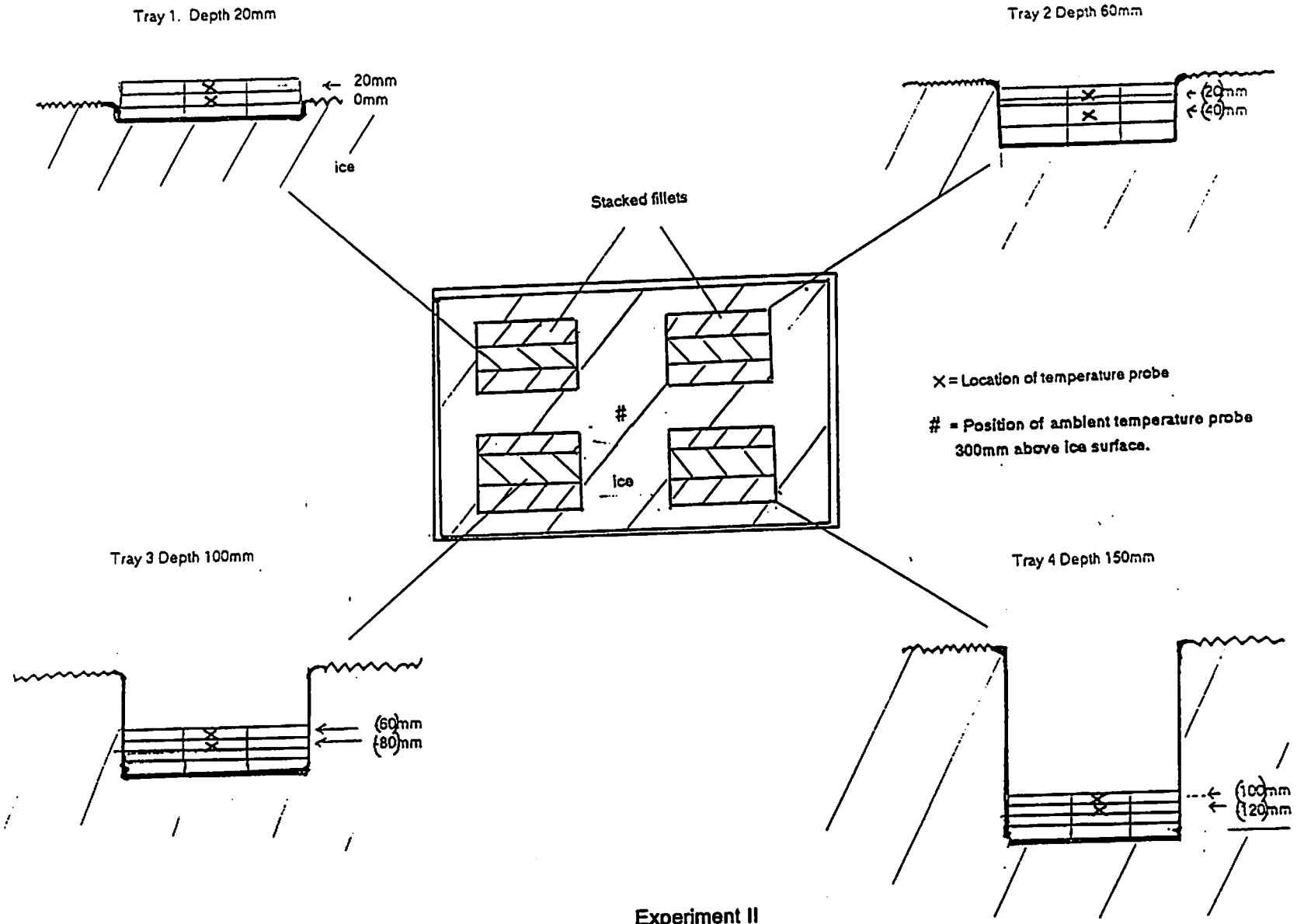
It was observed that the temperature of a top fillet after six hours was directly related to its height above/below ice level, although none of the top fillets remained below 5°C (Table 2, figure 5).

For top fillets (after 6 hours) a 40mm lowering in height compared to ice level appeared to correspond to approximately 1°C reduction in fillet temperature. The advantages for the more protected fillets beneath the top fillet were less pronounced.

Table 2 - Experiment II
Fillet Height and Fillet Temperature After a 6 Hour Period

Fillet Height Above/(below) Ice Level (mm)	Fillet Temperature °C
20 *	8.8
0	4.5
(20) *	7.1
(4)	4.6
(60) *	6.5
(80)	3.8
(100) *	5.5
(120)	4.0

* denotes top



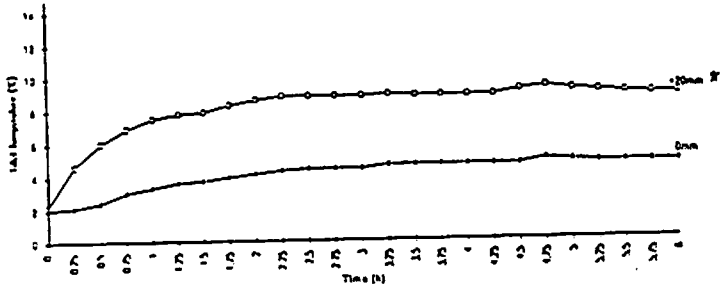
Experiment II

Diagram of fillets stacked in reiced trays of 20mm,60mm, 100mm, and 150mm depth.

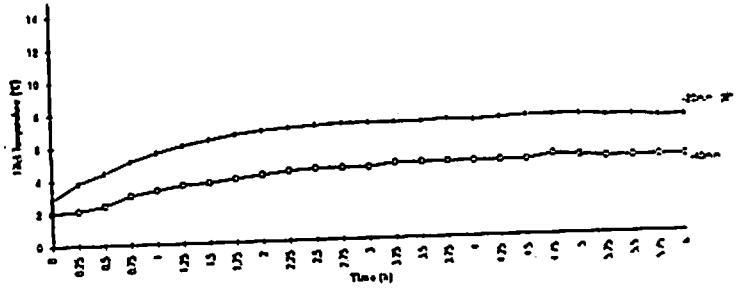
Figure 4.

Average Ambient Temperature 21.5 `C

Tray 1. Depth 20mm

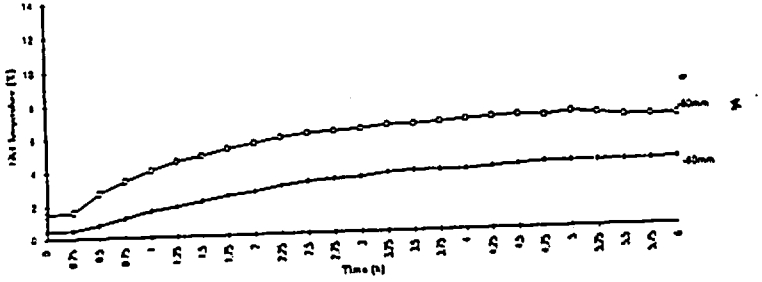


Tray 2 Depth 60mm

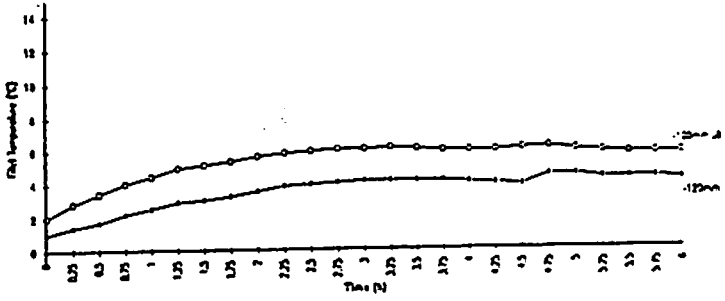


* Denotes Top Filet

Tray 3 Depth 100mm



Tray 4 Depth 150mm



Experiment II

Graphs of fillet temperature (`C) vs time (h) for fillets stacked in reiced trays 20mm, 60mm, 100mm, and 120mm deep.*

Figure 5.

6. Experiment III - The Effect of Air Movement on Fillet Temperature

6.1 Introduction

The results of the previous studies had shown the average air movement over products on commercial retail display to be 0.3m/s with a maximum of 1.5m/s recorded in one particular retail van.

Fillets stacked at different levels were subjected to an air movement of 1.0m/s to assess the effect of air movement on product temperature.

6.2 Method

Four trays, two x 20mm deep and two x 100mm deep were embedded in the ice bed (*figure 6*). Trays were separated by a 600mm high perspex shield resulting in one 20mm and one 100mm tray on either side. A single 100mm diameter 240v fan unit was placed approximately 1m away from the trays at 90° to the shield, to give 1m/s air movement 100mm above ice level. The screen slowed air movement to 0.1m/s 100mm above ice level on the protected side.

Fillets were stacked in trays on either side of the screen to give top fillet heights of 20mm above and (60mm) below ice level. Temperature probes were inserted into the top fillets and the ones directly below.

Air temperature was monitored at hourly intervals 300mm above the ice level. Trays were re-iced and fillet temperatures were recorded over a 6 hour period.

6.3 Results

Average ambient air temperature for each air speed was 19.6°C.

Ice was observed to melt away from trays 1 and 3, subjected to 1.0m/s at about twice the rate of trays 2 and 4 (0.1m/s).

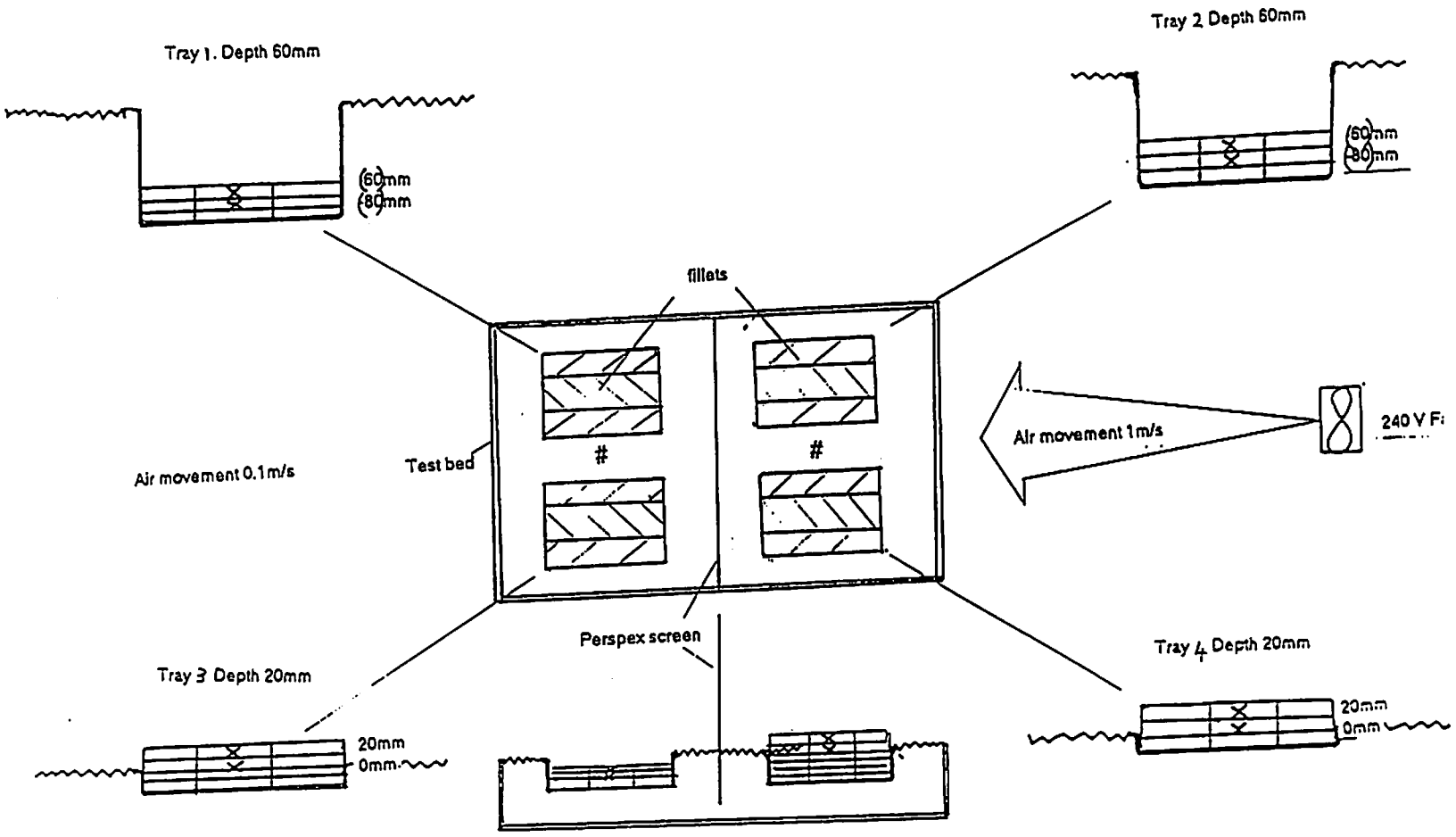
It was found that fillets above ice level subjected to a greater air movement warmed up more rapidly, while fillets below ice level warmed up at a slower rate. (*figure 7*, Table 3). After 6 hours a top fillet 20mm above ice level, subjected to 1.0m.s air movement (tray 3) was found to be 2°C warmer than the equivalent fillet subjected to 0.1m/s (tray 4). Both fillets had a final temperature above 5°C.

Conversely a top fillet 60mm below ice level subjected to 1.0m/s (tray 1) was slightly cooler than the equivalent fillet subjected to 0.1m/s (tray 3), but again both fillets had a final temperature above 5°C (Table 3). The results suggest that the well of cold air protects fillets from air movement.

Table 3 - Experiment III
Fillet Temperature (°C) Subjected to 0.1m/s and 1.0m/s Air Movement 100mm above ice level after 6 hours

Fillet Height above/(below) tray level (mm		Fillet Temperature °C		Difference in fillet temperature °C
		Air Movement 0.1m/s	Air Movement 0.1m/s	
20	*	8.8	10.8	+ 2
0		5.5	4.4	-0.9
(60)	*	9.0	7.7	-0.3
(80)		4.1	3.7	-0.4

* Denotes Top Fillet



- Position of ambient temperature probe 300mm above ice surface.

X = Location of temperature probe.

Experiment III

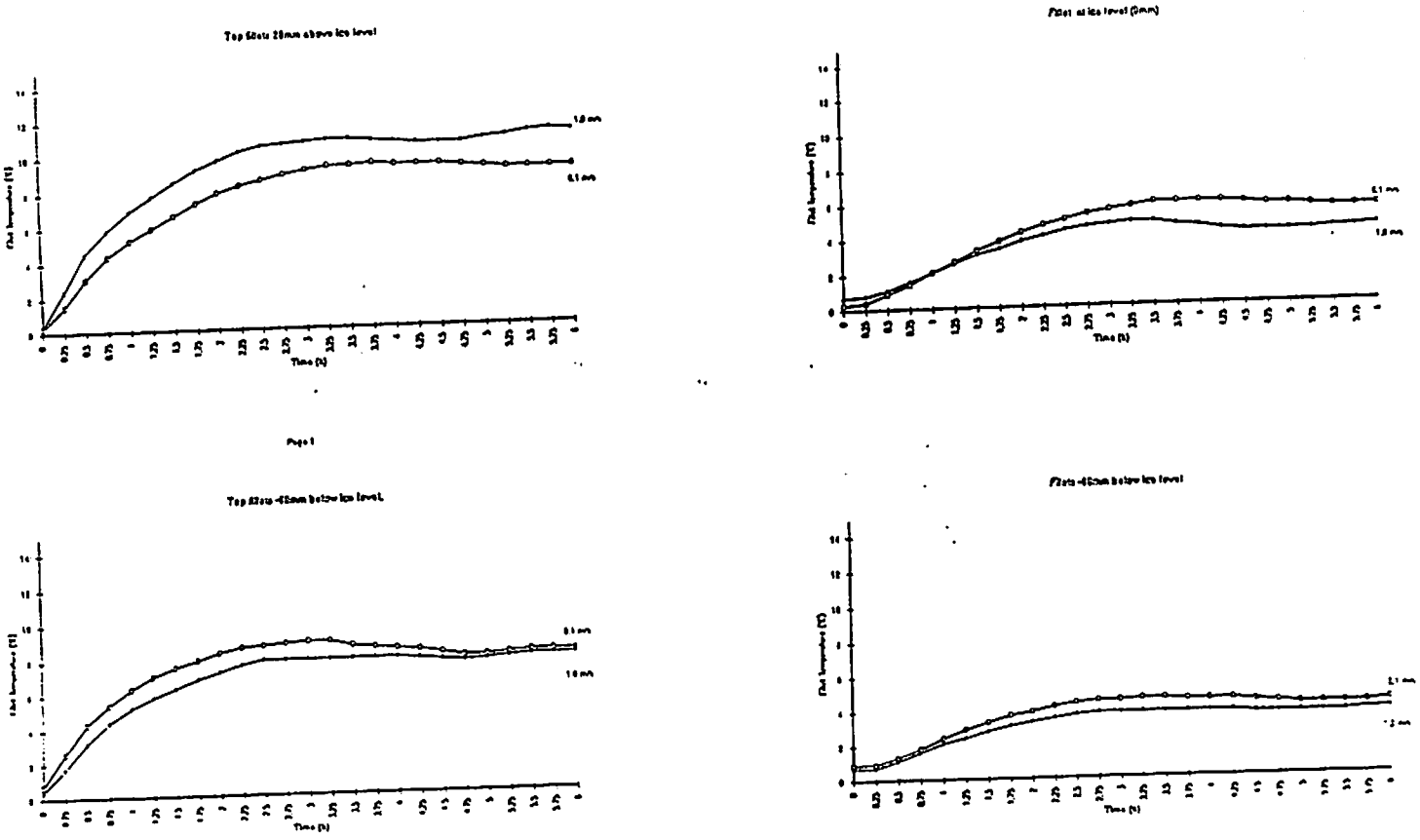
Diagram showing location of temperature probes in fillets stacked at different hights in reiced trays subjected to air movement of 1m\s and 0.1 m\s.

Figure 6.

Average Ambient Temperature 19.6 °C

Top fillets

Fillets stacked directly beneath top fillet



Experiment III

Graphs to show the effect of 0.1 m/s and 1.0 m/s air movement on fillets stacked above and below ice level.

Figure 7.

7. Experiment IV - The Effect of Individual Tray Covers on Fillet Temperatures

7.1 Introduction

The results of the previous experiment showed 1.0m/s air movement to increase the rate of fillet warming above ice levels.

In this next trial individual tray covers were used to prevent air movement and trap the cold well of air around the fillets. A fan was used to create an air movement of 0.3m/s over the display to simulate average retail conditions.

7.2 Method

Four trays two 60mm deep and two 100mm deep, were embedded in crushed ice (*figure 8*); fillets were stacked in the trays to give a top fillet height of 20mm and 60mm below ice level respectively. Temperature probes were inserted into the top fillets and ones directly below. One 60mm and 100mm tray were covered with 3mm thick perspex lids (285mm x 350mm). Trays were slotted on one edge to allow probe wires to exit, maintaining a good "fit" and minimising small gaps. Trays were re-iced and ambient/fillet temperature was recorded for 6 hours.

7.3 Results

Average temperature 300mm above ice level was recorded as 19.7°C.

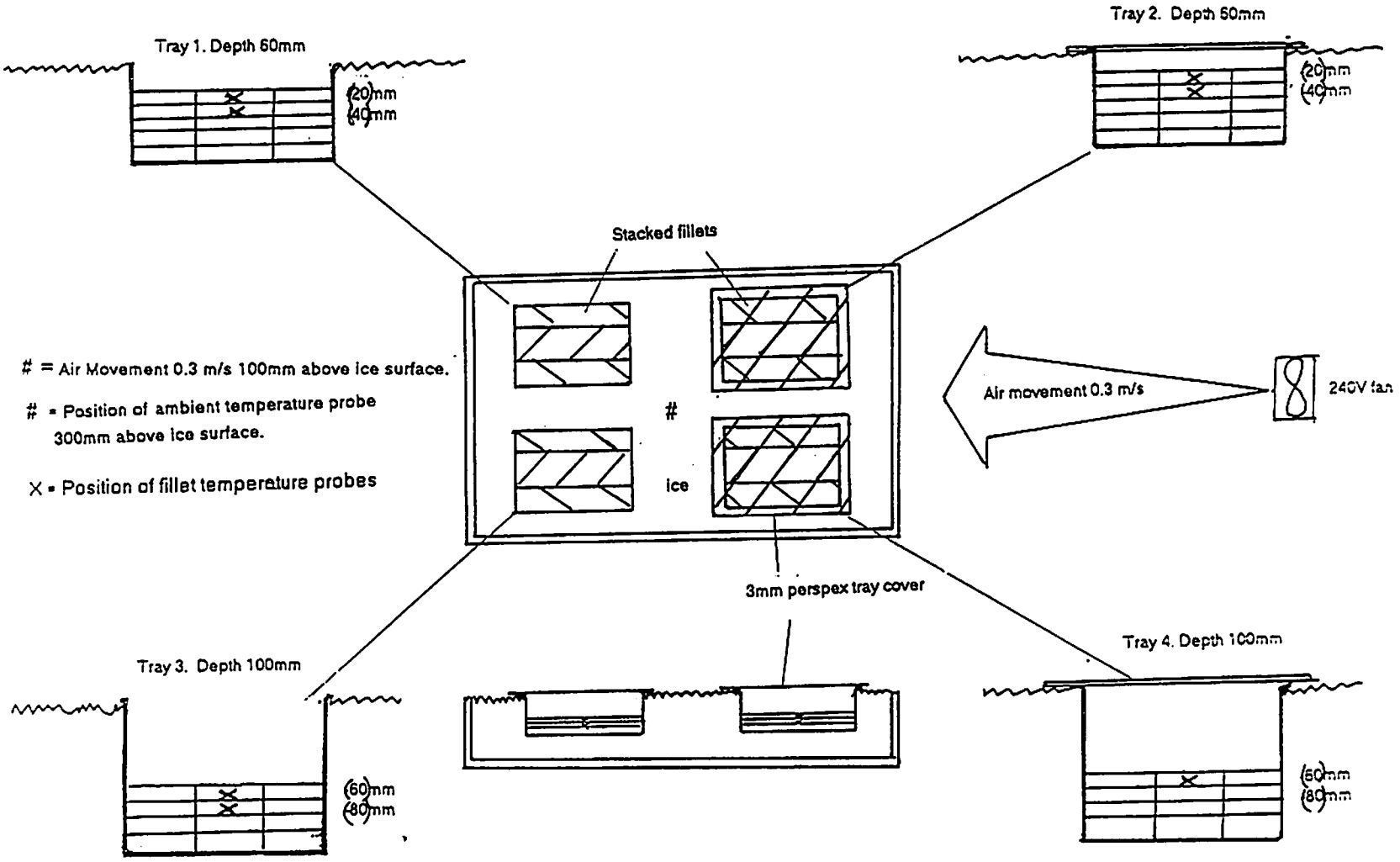
Individual covers were found to reduce the rate of fillet warming (Table 4 and figure 9). Covered top fillets at (20)mm and (60)mm below ice level were 1.6°C and 2.2°C cooler respectively compared to uncovered fillets after 6 hours. Fillets directly beneath the top fillet also benefited from the use of a cover. Covered fillets -40mm and -80mm below ice level were 1.3°C and 2.0°C cooler than identical uncovered fillets (Table 4).

The perspex covered top fillet (20)mm below ice level had a final temperature greater than 5°C but was significantly lower than the equivalent fillet in a tray with no cover. The perspex covered top fillet (80)mm below ice level had a final temperature of 4.3°C after 6 hours.

Table 4 - Experiment IV
Fillet Temperature for Uncovered and Individual Covered Trays after 6 Hours

Fillet Height above/(below) tray level (mm)	Fillet Temperature °C		Different in Fillet Temperature °C
	Uncovered	Covered 3mm Perspex	
(20) *	7.6	6.0	-1.6
(40)	4.3	3.0	-1.3
(60) *	6.5	4.3	-2.2
(80)	3.8	1.8	-2.0

* Denotes Top Fillet



Experiment IV

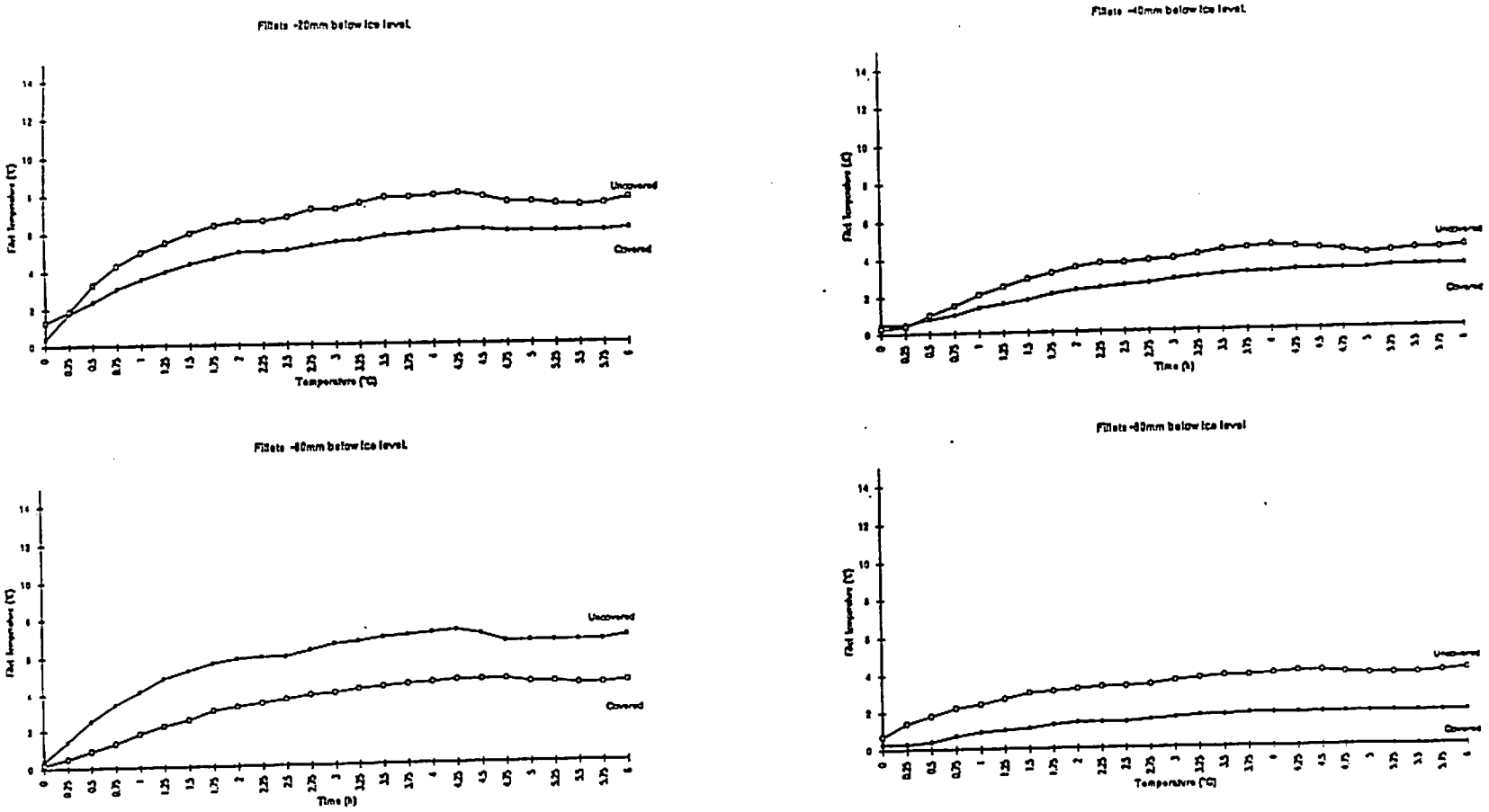
Diagram to show the location of temperature probes in fillets stacked in reiced trays with individual covers. (Air movement 0.3m/s to simulate an average retail enviroment.

Figure 8.

Average ambient temperature 19.7°C

Top fillets

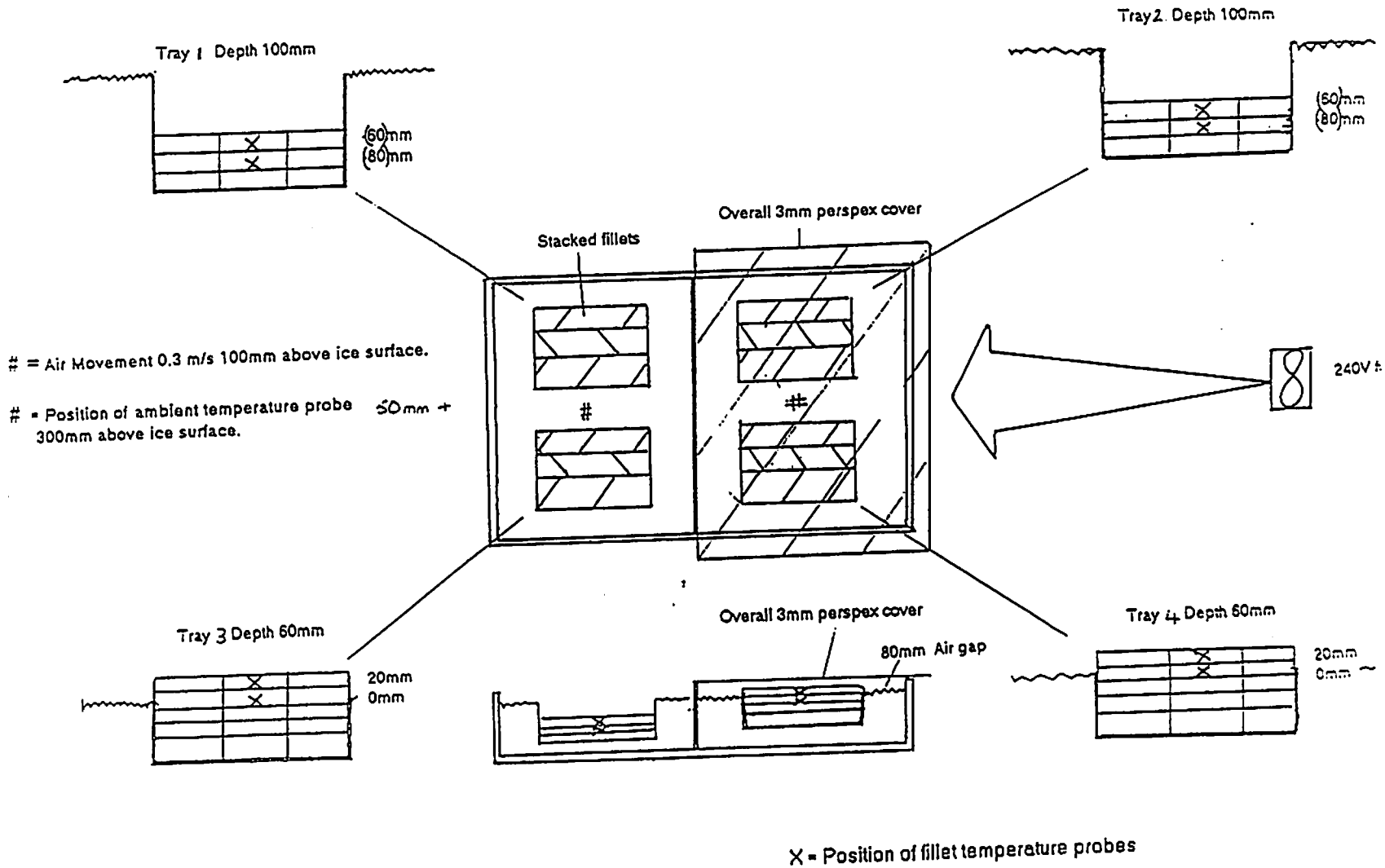
Fillets directly below a top fillet.



Experiment IV

Graphs to show the effect of individual covers on the temperature of fillets stacked in 60mm and 100mm trays.

Figure 9.



Experiment V

Figure 10.

Diagram to show the location of temperature probes in fillets stacked in reiced trays with an overall 3mm perspex cover including a 80mm air gap between the ice. (Air movement 0.3m/s to simulate an average retail enviroment)

8. Experiment V - The Effect of an Overall Cover on Fillet Temperature

8.1 Introduction

In this trial a large overall cover was used to cover two trays with air gap between the ice and cover, some were fillets stacked above ice level. A fan was used to give an air movement of 0.3m/s above the bed to simulate air movement in an average retail environment.

8.2 Method

Four trays, two 60mm deep and two 100mm deep, were embedded in ice (*figure 10*). Sheets of 3mm perspex were used to form a partition and full cover, totally enclosing a 60mm and 100mm tray, giving an air gap of 80mm between ice and perspex. Fillets were stacked in trays to give top fillet height of 20mm above and 60mm below ice level. Temperature probes were inserted into the top fillet and the one directly below.

Fillet temperature and ambient air temperatures 50mm and 300mm above ice level were recorded over a 6 hour period. The bed cover was removed at 2 hour intervals for 2 minutes to allow re-icing of the trays.

8.3 Results

Average air temperature 300mm above ice level was 18.7°C.

The average air temperature 50mm above ice level over the uncovered trays was 14.5°C, compared to 7.9°C measured 50mm above ice level in the 80mm air gap between ice and perspex.

The overall cover significantly reduced the rate of which fillets warmed up. (Table 5, *figure 11*). The covered top fillet 20mm above ice level had a final temperature of over 5°C. The covered top fillet (60)mm below ice level had a final temperature of 3.8°C after 6 hours. The covered top fillets at (20)mm and (60)mm were 4.5°C and 3.7°C cooler respectively compared to uncovered fillets.

Fillets directly beneath the top fillet also benefitted from the use of a cover. Fillets at 0mm and (80)mm below ice level were 2.9°C and 1.8°C cooler than identical uncovered fillets.

Table 5 - Experiment V
Fillet Temperature for Uncovered and Covered Trays with a Large 3mm Single Cover after 6 Hours.

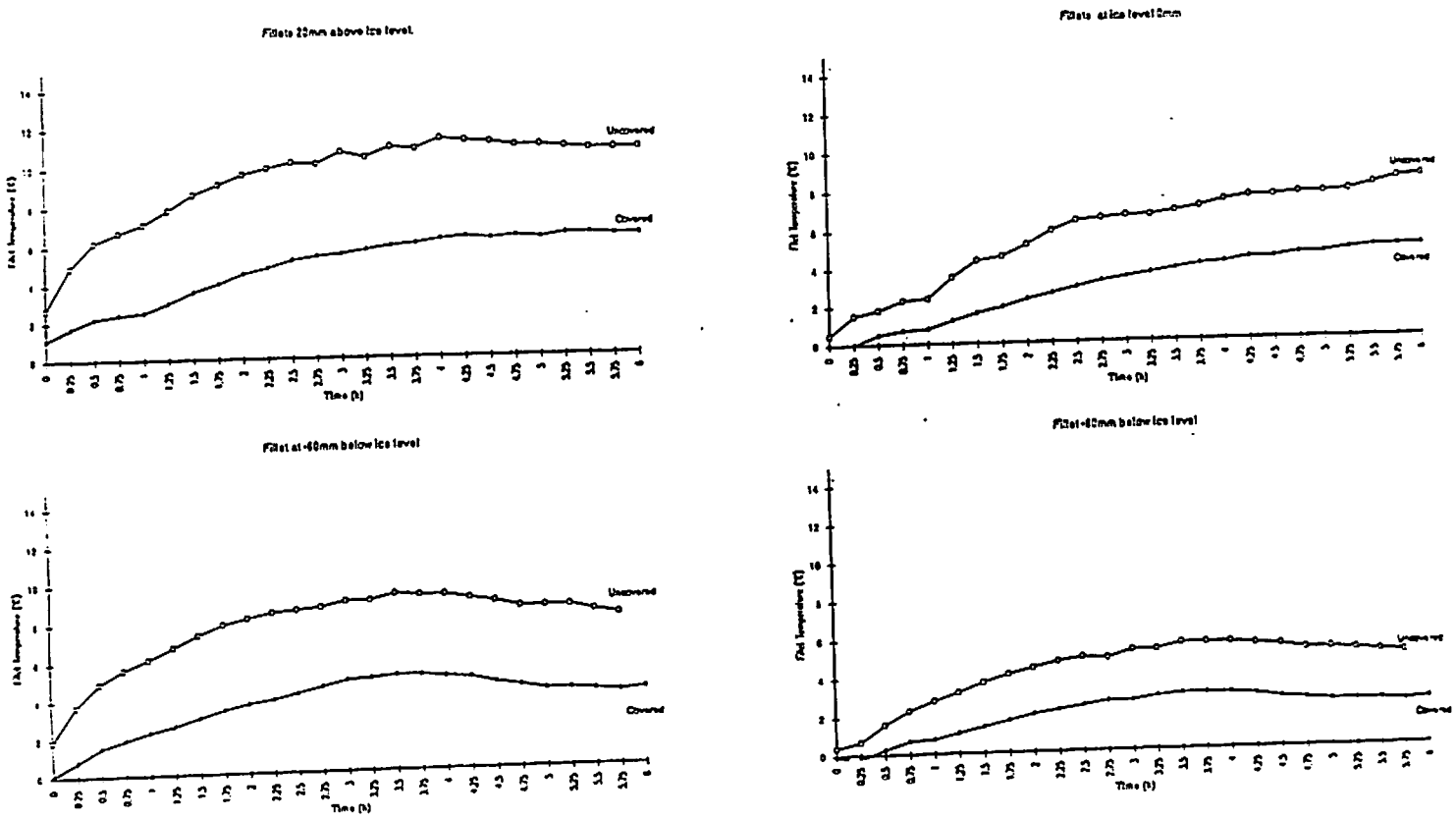
Fillet Height above/(below) Tray Level (mm)		Fillet Temperature °C		Difference in Fillet Temperature °C
		Uncovered	Covered	
20	*	10.5	6	-4.5
0		7.4	4.5	-2.9
(60)	*	7.5	3.8	-3.7
(80)		4.0	2.2	-1.8

* Denotes Top Fillet

Average Ambient Temperature 18.7°C

Top Fillets

Fillets stacked directly beneath a top fillet.



Experiment V

Graphs to show the effect of an overall cover (with 80mm air gap) on the temperature of fillets stacked above and below ice level in reiced trays

Figure 1.1.

9. Experiment VI - The Effect of a Fan Inside the Overall Cover to Circulate Chilled Air

9.1 Introduction

It was thought that fillet temperature could be further reduced by circulating the cold air trapped between ice and cover around the fillets. A small fan was introduced into the air gap to give 1m/s air movement around the covered fillets. The fan unit was 100mm diameter and powered by 1.5V at 1.2A. An air speed of 1m/s was chosen for experimental purposes only. An airspeed of 0.3m/s or less is generally recommended in refrigerated stores to minimise ice loss and the drying of the fish.

9.2 Method

Apart from the above, the trial was identical to that previously described in 2.6. It is shown in *figure 12*.

9.3 Results

Average ambient temperature 300mm above ice level was 16.8°C.

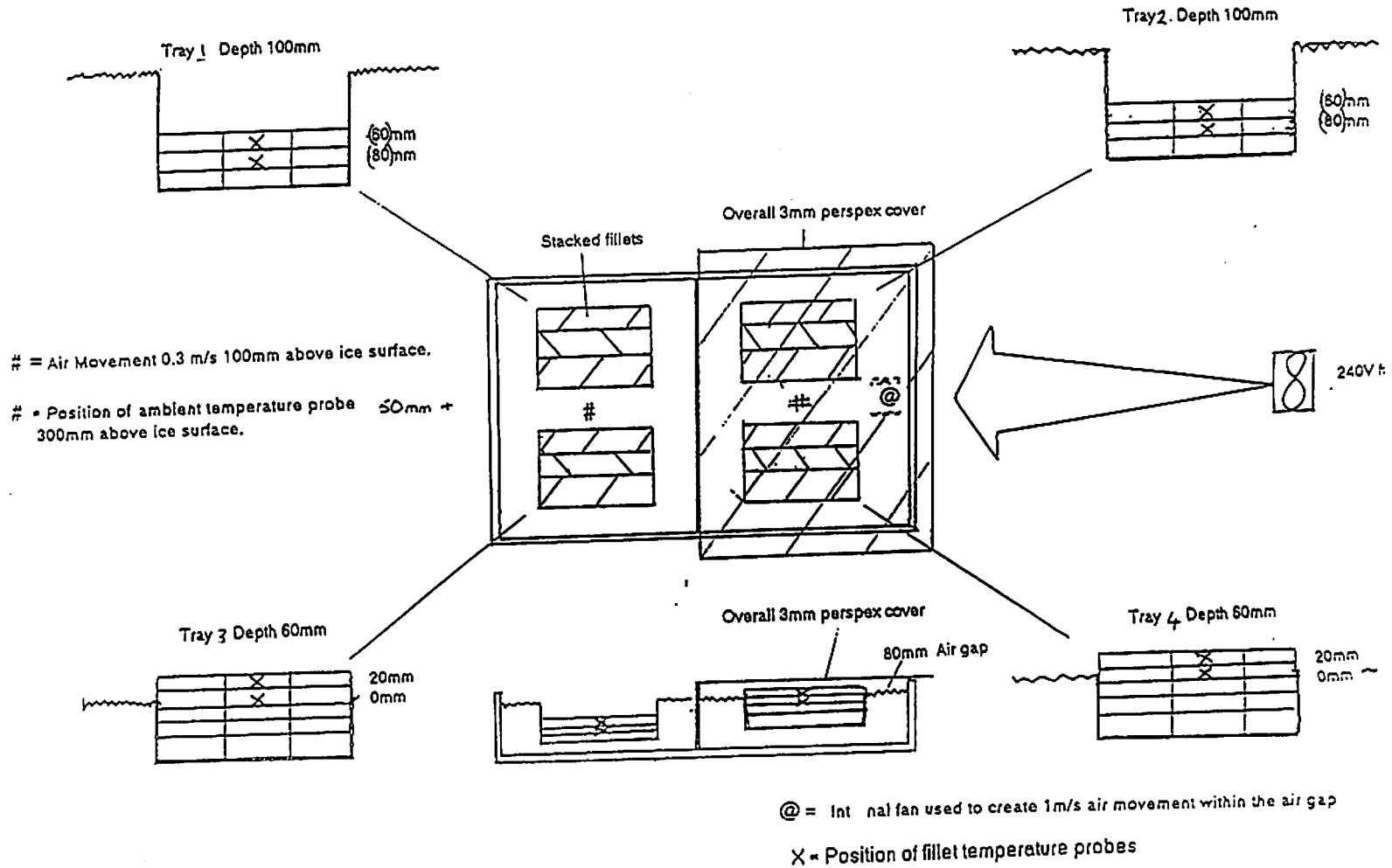
The average temperature 50mm above uncovered trays was an average 13.3°C compared to 6.8°C for the covered trays. Removal of the lid every 2 hours for re-icing had no significant effect on fillet temperature. Ice melted rapidly in close proximity to the fan blades. Fan blades made re-icing trays a difficult operation.

Air movement beneath the cover also reduced the rate of which fillets warmed up. (Table 6, *figure 13*). All covered fillets remained at or below 5°C after 6 hours.

Covered top fillets at 20mm above and (60)mm below the level of ice were 3.5°C and 2.3°C, respectively, cooler than the equivalent uncovered fillets after 6 hours. Covered fillets directly below top fillets at 0mm and (80)mm also benefitted from the use of a cover; respectively 1°C and 0.2°C cooler than uncovered fillets.

Table 6 - Experiment VI
Fillet Temperature for Uncovered and Covered Trays (1.0m/s) Air Movement in the Air Gap, After 6 Hours

Fillet Height Above/Below Tray Level (mm)	Fillet Temperature °C		Difference in Fillet Temperature °C
	Uncovered (0.3m/s)	Covered (1m/s)	
20	8.5	5.0	-3.5
0	6.5	4.2	-2.3
(-60)	4.9	3.9	-1
(-80)	2.5	2.7	-0.2



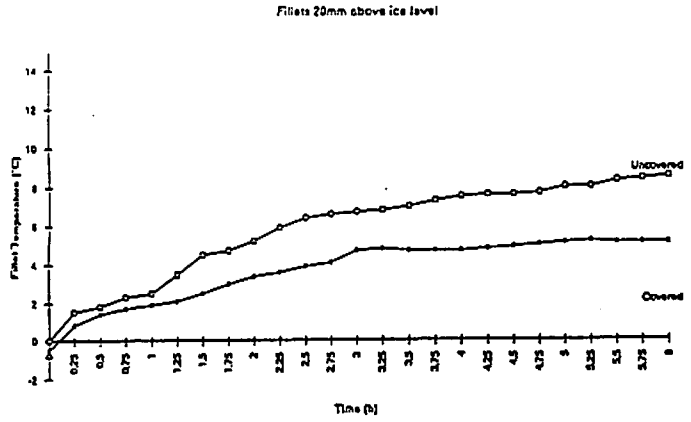
Experiment VI

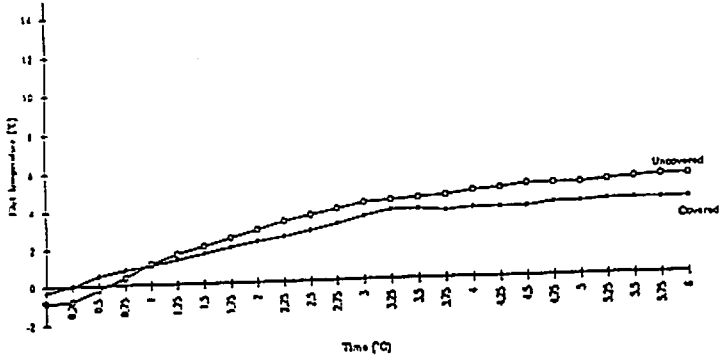
Figure 12.

Diagram to show the location of temperature probes in fillets stacked in raised trays with an overall 3mm perspex cover including a 80mm air gap between the ice. (Air movement 1 m/s WITHIN THE COVER)

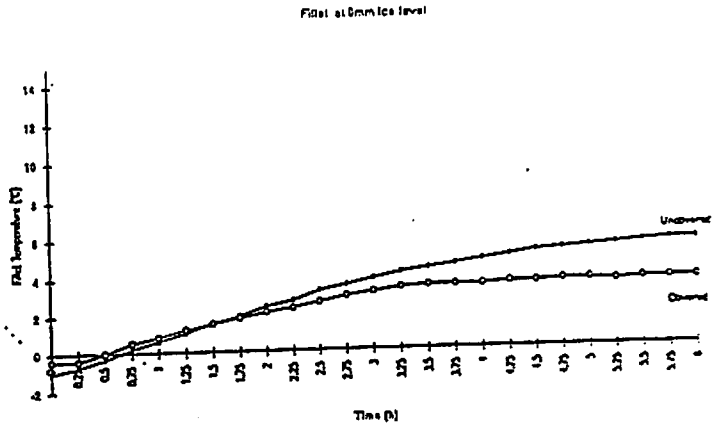
Average Ambient Temperature 16.8°C

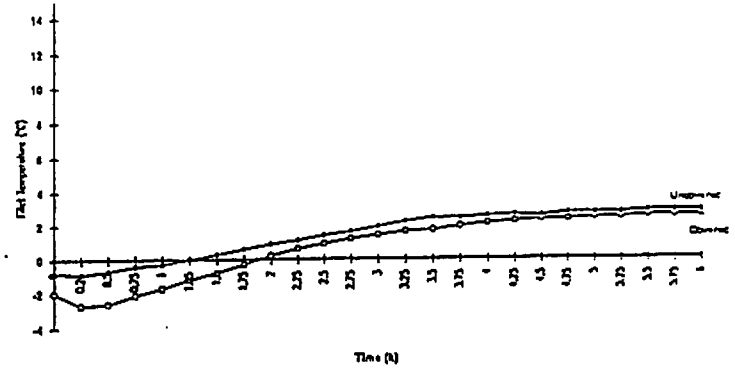
Top Fillets





Fillets stacked directly beneath a top fillet.





Experiment VI

Figure 12. Graphs to show the effect of an overall cover (with 1.0 m/s air movement within the 80mm air gap) on the temperature of fillets stacked above and below ice level in reiced trays.

10. Discussion

10.1 Tray re-icing plays a significant part in lower fillet temperature. However, it can be concluded that re-icing alone can not maintain fillets above ice level below 5°C for 6 hours but has a significant cooling effect on all fillets. Therefore, re-icing should be used in conjunction with other techniques for maximum chilling effect.

10.2 The position of a fillet in a tray is the most important factor governing the rate of warming. All fillets on top of a stack are especially vulnerable to rapid warming. Fillets directly beneath a top fillet warm up at a much slower rate.

10.3 In still air the temperatures of exposed fillets on top of a stack were found to be directly related to their height in relation to ice level. With an air temperature of 20°C a fillet at 0°C, on display 20mm above ice level can be expected to warm up above 5°C in less than 30 minutes. A top fillet stored at 100mm below ice level warmed to just over 5°C after 6 hours, but it would not be practical to store fillets at 100mm below ice level due to the poor presentation and large depth of shelf required. It can be concluded that fillets in a tray below ice level are protected by a well of cold air which slows the rate of warming.

10.4 Air movement at 1.0m/s accelerated the warming of fillets above ice level. Top fillets above ice level remained cooler when protected from air movement by a screen. It can be concluded that fillet stacking above ice level must be avoided especially in a retail environment with significant air movement, and that air movement over the products must be minimised. A top fillet stored 60mm below ice level remained unaffected by a 1.0m/s air movement above the tray, protected by the well effect.

10.5 Combined with re-icing, individual perspex tray covers had a significant and beneficial effect on maintaining a low fillet temperature; although a perspex covered top fillet 20mm below ice level could not be held below 5°C for 6 hours.

10.6 Using an overall cover with 80mm air gap, had similar beneficial effects but top fillets above ice level could not be held below 5°C indefinitely.

10.7 Fillet temperature was not significantly lowered by placing a fan in the air gap between ice and cover.

11. Recommendations

In summary the following procedures are considered good practice for retailers.

1. Any product storage system using ice and trays should be re-iced around the trays for maximum cooling effect to be transferred to the product.

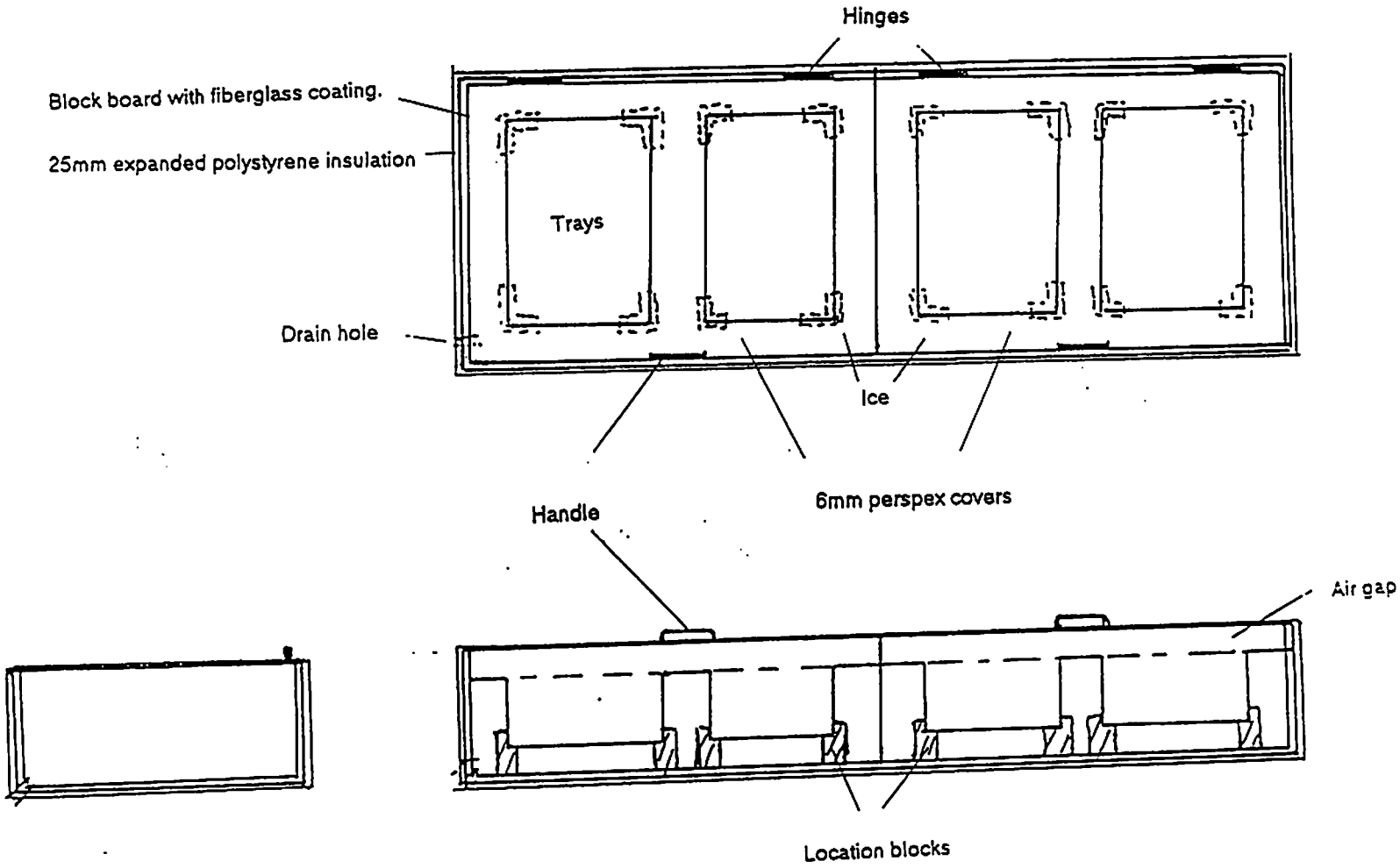
2. Fillets should not be stacked higher than ice level, they should preferably be below ice level in a well of cold air.

3. Fillets should be shielded from air movement.

4. Covering individual trays or an overall cover with an air gap is beneficial.

5. Combining the above and with good practice it may well be possible to satisfy the legislation.

Future work may involve the construction of equipment with a divided overall cover which could be installed in a mobile van. The design would be sufficiently insulated with adequate drainage. A possible design is shown in Figure 14, the split cover minimises unnecessary disturbance of the cool air. Covers have the added advantage of protecting cooked and smoked products from insects and wet fish contamination.



Experiment VI

Possible design of insulated tray system for maintaining cooked products below 5°C in a mobile retail van.

Figure 14