

1st IIR International Conference on the Cold Chain and Sustainability
Cambridge, UK - 29th to 31st March 2010

Programme and Discussion Report

PLENARY SESSION IN DIAMOND ROOM

- 8.30 Introduction from R Heap, Conference Chairman
8.50 Welcome from X Meignien, Deputy Director, IIR
9.00 Performance of the cold chain, from J Guilpart, Former head of refrigeration processes engineering research unit of Cemagref, French delegate to the IIR

PAPERS SESSION 1 - TUESDAY 30TH MARCH 2010 (9.35 TO 10.35)

Refrigerants & refrigeration in the future

Diamond Room, Chairman Andy Pearson

9.35	<p>Reducing the environmental impact of refrigeration: an Ineos Fluor perspective R Low <u>Question or discussion point from SF Pearson, Star Refrigeration</u> Why are you not considering CF3I? Author's response We have evaluated the molecule and although it showed good thermodynamic properties and was an effective flammability suppressant, we decided it was not an appropriate candidate for inclusion in refrigerant blends. This was for three reasons: firstly we found its thermal and chemical stability to be deficient in autoclave testing; secondly, it is known to have a small but non-zero ozone depletion potential and this raised questions over its viability; and we were also concerned about the long term toxicological behaviour of the molecule. As an additional point, large scale adoption of it would have placed a serious load on the global production capability for elemental iodine.</p> <p><u>Question or discussion point from S Sundarsan, Sundaresan Consulting Services</u> The trend towards higher pressure refrigerants for compactness in equipment (R12→R22→R410A) Would this trend continue now R32/HFoZ234yf blends are looked at as R22 alternatives? Author's response The attraction of equipment size and pressure drop reduction (with concomitant gain in system performance) is evident from the demonstrated move up the pressure scale from R-22 to R-410A. The HFO fluids under current investigation all have vapour pressures similar to R-134a, in other words relatively low when compared to that of R-410A. So for the equipment currently using R-407A/C or R-410A it may be that rather than go to an HFO blend - which would probably appear thermodynamically rather like R-407A or R-407C - equipment manufacturers choose instead to adapt to use of R-32 if safety standards and risk assessment permit. An application and sector specific consideration of how best to reduce TEWI, rather than headline refrigerant GWP, is the rational way to make best progress in overall reduction of the environmental footprint of refrigeration or air conditioning systems. Recent experience in the automotive sector has shown that the best TEWI (or LCCP) for a given application is not necessarily achieved using the refrigerant with the lowest headline GWP - energy efficiency is still the dominant factor.</p>	244
9.55	<p>Sustainable refrigerant selection in binary blends of the R1234yf – hydrofluoroethers S Artemenko, D Nikitin, S Haddad, V Mazur <u>Question or discussion point from A Pearson, Star Refrigeration</u> Is there a risk that the more reactive blend components will break down or react with each other perhaps in the presence of moisture or acid? Author's Response There is some risk that the reactive blend components will impair the refrigeration unit performance. Here we considered only thermodynamic aspects of fluorinated ether selection and narrowed the range of alternative substances. Sustainable decision should meet all requirements and restrictions.</p>	204

10.15	<p>F-gas containment - two UK led projects on reducing refrigerant emissions & leakage D Cowan, I Chaer, G Maidment</p> <p><u>Question or discussion point from D Fitzmaurice, PED Refrigeration Consultants</u> You indicate only some of the companies participating in the original survey have taken measures to reduce leakage, Have you any comments on why this might be so?</p> <p>Author's response Some companies have not yet responded to our follow up questionnaire, so we don't know what steps they may have taken to reduce leakage.</p>	251
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Food quality, safety and microbiology

Chadwick Room, Chairman Jacques Guilpart

9.35	<p>Growth potential of listeria monocytogenes in salted diced bacon A Beaufort, H Bergis, P Garry</p> <p><u>Question or discussion point from A Le Bail, Oniris</u> Do people eat diced bacon raw? This is supposed to be cooked.</p> <p>Author's response A recent survey in France showed that about 15% of consumers do eat them raw.</p> <p><u>Question or discussion point from S Estrada- Flores, Food Chain Intelligence</u> Tom Ross in the University of Tasmania developed a Lm growth model for small goods that may contain nitrates. Can you comment on the potential effect of nitrites on the products potential to support growth of listeria M?</p> <p>Author's response Yes, nitrates could be influent. But I haven't been told that nitrates was added in this food</p> <p><u>Question or discussion point from A Geeraerd, BIOSYST-MeBioS</u> EU- regulation 2073/2005 is regarding the physicochemical characteristics allowing growth of L.monlytogenes, lagging behind scientific literature; it is on the safe side.</p> <p>Author's response Sure, limits are not exactly the same in EU regulations and in scientific literature.</p> <p><u>Question or discussion point from A Geeraerd, BIOSYST-MeBioS</u> Does Sym previous not incorporate the effect of a background flora (Jarneron effect)?</p> <p>Author's response For the growth, only 2 factors may be taken into consideration simultaneously between 4 (temperature, pH, a_w, organic acid) inr the "interface module". The associated microflora can't be taken into consideration.</p>	189
9.55	<p>Chilling individual retail pots of hot-filled soups and sauces using air to meet cook-chill guidelines C James, C Bobst, H Fleury, S Palpacelli and S James</p> <p><u>Question or discussion point from A Le Bail, Oniris</u> The temperature span for meal chilling in France is 63°C to 10°C not 70°C to 10°C.</p> <p>Author's response OK</p>	207
10.15	<p>Possible use of negative ions and ozone as anti bacteria mixture G Panozzo, L Fedele, M Franceschi, S Rossi, D Spolaor</p>	217

Modelling & predictive tools

Tower Room, Chairman Monica Axell

9.35	<p>Theoretical analysis of the coupling of heat and mass transfer of fruits and vegetables in precooling L Bin, C Jinghui, H Yanhong, Y Xingying</p> <p><u>Question or discussion point from T Pham, University of New South Wales</u> Please explain "structure parameter". Did you assume that the skin was the only resistance to mass transfer? How about internal resistance?</p> <p>Author's response From the structure of the fruit, the skin is denser than that of the internal tissue, so the skin resistance was the key factor, the internal resistance was ignored.</p>	195
9.55	<p>Thermal modelling of catering meals under blast-cooling J Rabi, J Guilpart, E Derens, A Duquenoy</p>	261

Question or discussion point from S James (FRPERC)

Why calculate an average h ? The critical thing is the slowest chilling food?

Author's response

While the slowest heat transfer coefficient h_c is indeed the critical one in terms of food chilling, it is also worth bearing in mind its corresponding statistical relevance as it occupies the left-hand tail of a "Gaussian-like" distribution that was obtained for such thermal parameter.

In addition, as far as a Bayesian approach for HACCP is concerned, average value h together with its related standard deviation (as calculated from the aforesaid distribution) is quite useful.

Question or discussion point from S James (FRPERC)

Why use same h top and bottom they are very different?

Author's response

Top and bottom heat transfer coefficients must not be rigorously the same. However, as commented in the paper text (at the bottom of page 3), "although $h_{c,inf} \neq h_{c,sup}$ could indeed bring an extra degree of freedom, the fitting-search procedure for distinct coefficients would become more complex".

Furthermore, in the majority (i.e., about 60%) of the situations observed in situ, neighbouring food containers were vertically separated from each other by a distance of 0.095 m or lower. In view of such relatively small distance, the bottom heat transfer coefficient $h_{c,inf}$ for the container in the level above might be close to (if not the same as) the top heat transfer coefficient $h_{c,sup}$ referring to the container at the level below.

Question or discussion point from Anon

The containers are assumed to have zero thickness. How does this affect the results?

Author's response

In fact, the conductive resistance (l_{wall}/\square_{wall}) associated to the lower wall of food containers was neglected in comparison to the remaining thermal resistances ($1/h_c$ and $l_{1/2}/\square_{food}$) so that Equation (3) could be obtained.

From typical values for the heat transfer coefficient ($h_c = 12.0 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$), foodstuff half-thickness and thermal conductivity ($l_{1/2} = 0.015 \text{ m}$ and $\square_{food} = 0.488 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$) and container wall thickness and thermal conductivity ($l_{wall} \sim 0.002 \text{ m}$ and $\square_{wall} \sim 0.300 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$), one observes that l_{wall}/\square_{wall} ($= 0.0067 \text{ W}^{-1}\cdot\text{m}^2\cdot\text{K}$) is one order of magnitude lower than either $1/h_c$ ($= 0.0833 \text{ W}^{-1}\cdot\text{m}^2\cdot\text{K}$) or $l_{1/2}/\square_{food}$ ($= 0.0307 \text{ W}^{-1}\cdot\text{m}^2\cdot\text{K}$) while only answering for 5.5% of the total thermal resistance ($= 0.1207 \text{ W}^{-1}\cdot\text{m}^2\cdot\text{K}$).

Such additional thermal resistance can be included in future work (however, at the expenses of necessarily writing Equation (3) under a relatively more complex form).

Question or discussion point from Anon

Cooling at -20°C (20°C below zero), is radiation included?

Author's response

In view of the relatively simple approach adopted, radiation has not been yet included.

By assuming air to be transparent, foodstuff samples may then transfer heat via thermal radiation between themselves and/or to the surrounding blast-cooling cell walls.

The former can be neglected as foodstuff samples are approximately at the same temperature.

When assessing the later transfer rates, care should be exercised with respect to view factors from food containers relative to the cell walls (e.g., containers at the top of the supporting trolley are more exposed than those at the trolley middle).

Question or discussion point from Anon

Is there phase change during the process?

Author's response

At the end of the blast-cooling operation, foodstuff samples were observed to be above 0°C ; hence, as far as water content is concerned no phase change need be considered. Other prospective phase changes were not accounted for as temperature-time profiles have been properly simulated.

Question or discussion point from Anon

The containers are assumed to have zero thickness. How does this affect the results?

Author's response.

Not included and will be included in future work	
<p><u>Question or discussion point from Anon</u> Cooling at -20°C (20°C below zero), is radiation included? Author's response. No</p> <p><u>Question or discussion point from Anon</u> Is there phase change during the process? Author's response. There is no obvious phase change besides on the surface of the food.</p>	

10.35 to 10.55 COFFEE BREAK, Dining Room and Diamond Room

PAPERS SESSION 2 - TUESDAY 30TH MARCH 2010 (11.00 TO 1.00)

Refrigerants & refrigeration in the future

Diamond Room, Chairman Andy Pearson

11.00	Lubricating the Future of Refrigeration – CO ₂ : Effective Lubrication of Carbon Dioxide Refrigeration R Rogers	222
11.20	<p>Using natural refrigerants in the cold chain A Pachai, M Jones</p> <p><u>Question or discussion point from S Tassou, Brunel University</u> How do the modeling results relate to results for actual installations? Author's response In the project group some of the participating companies were able to verify the results and it came out pretty much as predicted. There is just one comment here to remember: no out-put became any better than the in-put given by the user of the software.</p> <p><u>Question or discussion point from S Tassou, Brunel University</u> In the modeling of the transcritical system does the modeling switch to transcritical operation at low ambient temperatures? Is this done manually by specifying the transaction temperature or automatically by the model? Author's response The switching between transcritical and subcritical is using the same algorithms as used in the little software, this can be down loaded from the same place as the Pack Calculation software which is: http://ipu.dk/English/IPU-Manufacturing/Refrigeration-and-energy-technology/Downloads.aspx</p> <p><u>Question or discussion point from K Visser, KAV Consulting</u> Have you considered improving the overall energy efficiency of building cooling systems by using heat recovery from the transcritical compressor discharge to heat the water or to heat water for reheat/heating purposes, even in hot climates? Author's response Heat recovery is already included in the package. We already included free-cooling as well. If we had some more funding we are considering adding heat-pumps in to the systems, which in many cases would also make good sense. All projects generate a lot of ideas but time and resources makes it necessary to formulate the boundaries and here is where we got to in first step. Hopefully we can raise money to enhance the product</p> <p><u>Question or discussion point from SF Pearson, Star Refrigeration</u> As well as two stage compression have you considered the parallel compression system? Author's response Both parallel compression and Voorhees compression were considered but to keep it manageable and over seeable it was decided to leave them out for now.</p>	223
11.40	<p>Ammonia a safe refrigerant? L Rolfsman</p> <p><u>Question or discussion point from S El Harch, Aleaf Refrigeration</u> Is it worth introducing an educational tax that would be used to finance training, (eventually free), to improve the standard among engineers which will result in fewer accidents when</p>	226

	<p>operating ammonia plants? Author's response This is an issue well outside my technical scope. Education is crucial for the operation and service for any refrigeration plant. The demand for certification and the results in leakage is well documented in the two countries with close to 20 years experience Sweden and the Netherlands regarding HFC media. In Sweden the preventive maintenance resulted in a lower volume of service load when the outdoor temperature started to rise in May. How the education should be financed is a national or even corporate issue. My main point is that the need for maintenance must be understood by the people allocating money in business organizations. Today they very often have a nontechnical background</p> <p><u>Question or discussion point from SF Pearson, Star Refrigeration</u> Would it be good to develop semi-hermetic compressors and what would be the difficulty? Author's response Answer to part one Yes. The reason is that the main cause of leakage in systems with open compressors is the shaft seal. One other reason may be that internally cooled motor windings may be harder loaded and in that way be designed smaller compared to aircooled solutions. The commercial reason apart from lower costs is a mental one for potential buyers. They may believe that the risk for major leaks will be lower. Part two about difficulties. There may be two main hurdles to take into consideration. Motorwindings regardless of material do not like ammonia or water. Copper or aluminium will end up the same way in contact with the refrigerant and the often high content of water. Insulation in normal aircooled windings used to have one open spot each 3 meter the standard insulation is also not possible to use with ammonia. There exists insulation systems capable of handling ammonia. The other main hurdle is that ammonia gas has a very low heat capacity. This results in suction cooled designs is a too high volumetric loss. One solution tested with good results is cooling with high pressure gas+ oil with the motor for a screw compressor on the discharge side. Liquid injection is a bad solution due to spot cooling of the windings and the resulting thermal stress.</p>	
12.00	<p>Use of carbon dioxide for air conditioning and general refrigeration SF Pearson <u>Question or discussion point from M Worall, Nottingham University.</u> Can a CO₂ operation in transcritical region be controlled to operate in the sub-critical region? Author's Response Yes, the temperature of heat rejection depends on the temperature of the heat sink and the effectiveness of the heat rejection equipment. Most CO₂ systems that are designed to operate super-critical in warm weather spend most of their lives operating, at much higher efficiency, in sub-critical mode. Control of the expansion device can be as simple or as complicated as the designer decides. In general, devices for supercritical operation operate by opening to maintain a set pressure on the high side. Another type of device is required for sub-critical operation and may be a thermostatic expansion valve or some sort of float control. It is relatively easy to determine which type of device should be operating. In practice it would not be too in-efficient just to have two orifices, one for operation at super-critical condition and one for sub-critical, provided the load did not vary too much.</p> <p><u>Question or discussion point from A Gigiel, CCC Consultants</u> What happens to the salts in the water of the "once through" condenser? Author's Response As in a conventional evaporative condenser there is a tendency for dissolved solids in the water to become concentrated. The "Once Through Condenser" has provision for water overflow so that the degree of concentration can be controlled.</p> <p><u>Question or discussion point from I Chaer, London South Bank University</u> I would be grateful for a figure of the quantity of the water used per kw cooling or kgwater/kwh cooling and overall COP of the system compared to original COP. Author's Response In general one requires to evaporate about 100 l/h to reject 100kW of heat. However, as previously stated, it is normal to arrange an overflow to limit the increase in concentration of dissolved solids. If the overflow quantity is equal to the quantity evaporated it is relatively easy to see that the concentration of dissolved salts within the condenser will be doubled.</p>	225

	<p>The amount of overflow will be decided in accordance with the quality of water being used. Very soft water requires very little overflow. Very hard water should be treated to minimise the amount of overflow required. Because water is relatively expensive, most systems seem to work with less than two cycles of concentration (overflow equals evaporation rate). However shutting off the overflow completely as an economy measure is likely to have very expensive consequences.</p> <p>It is difficult to compare overall system CoPs because there are so many possible variables. The comparisons that I have made in the paper are restricted to compressor CoPs. This, if anything, is "unfair" to the system with evaporative condenser because fan power will be greater for a system with air cooled condensers. I assume you are asking about comparisons between CO2 systems using the evaporative condenser and CO2 systems using air cooled gas coolers under super-critical conditions. The supercritical CoP is unlikely to be greater than 2. As indicated in the paper the CoP of the compressor in the system using evaporative condenser is likely to be greater than 6. However, one must remember that the "supercritical" system will only operate under super-critical conditions in warm weather. In very cold weather there will be little to choose between the systems. Experience of supermarket systems suggests that year- round CoP of a "transcritical" CO2 system is likely to be higher than the CoP of a conventional R404A system in temperate climates.</p> <p><u>Question or discussion point from G Maidment , London South Bank University</u> Can you comment on the relative use of the ground source heat sink for operation of a subcritical CO₂ cycle? Author's Response It would be practicable to reject heat to a ground sink to produce a sub-critical CO2 system but I do not think it would be economic.</p> <p><u>Question or discussion point from K Visser, KAV Consulting</u> Have you considered using the evaporative in conjunction with air cooled condensing during warm weather, ie, evap condenser off during cold weather? Author's Response I had not thought of that but it could be done. Air cooled condensers are very effective in cold weather. The disadvantage from your point of view is that, where you come from, you need all the water you can get in warm weather for making beer."</p>	
12.20	Sensitivity of TEWI estimate – leakage and energy for CO ₂ as refrigerant in commercial refrigeration R Islam	174

Innovation in storage & transportation

Chadwick Room, Chairman Robert Heap

11.00	<p>Usefulness and subtlety of the overall coefficient of heat transfer in cooling containers G Labranque, A Kacimi</p> <p><u>Question or discussion point from D Finn, University College Dublin</u> Please elaborate on the approach for calculating ΔT – Linear or non- linear evolution? Author's response Our experiment method is based on a linear ambient temperature, because it's very difficult to estimate the time (duration) of the entire melting of gel packs, for varying ambient temperature profile. We can use the methodology for varying profile*, but the uncertainty will be larger. The goal of the approach is to evaluate a realistic co-efficient of heat transfer with an acceptable uncertainty, so we use a linear profile. *For varying profile: we must calculate the average of ambient temperature, taking into account the duration of each segment (temperature, duration).</p> <p><u>Question or discussion point from a A Al- Sahhaf</u> The cold packs are placed at the top and bottom of the box. Is there a maximum aspect ratio for the box? Author's response Yes, several configurations are possible. It depends on the product temperature range, the ambient temperature profile and the dimensions of the container. The position of gel packs must be adapted to the dimensions of the container, and also to the operating and logistic</p>	170
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	<p>constraints of the user.</p> <p>For the +2/+8°C, gel packs are placed at the top and bottom, or sometime at the top and on 2 sides, for durations more than 72 hours. It depends also, on the external temperature.</p> <p>For the frozen products (below -18°C), gel packs are generally placed on the six faces..</p>	
11.20	<p>Cryogenic refrigerated transport equipments tests: methodology and results</p> <p>G Cavalier, Ph Nol, N Valentin and B Amara</p> <p><u>Question or discussion point from A Foster, London South Bank University</u></p> <p>What are the main selling points of this system over the conventional DX system?</p> <p>Author's response</p> <p>The solution is silent; this is an advantage for distribution (PIEK Standards). Energy consumption is proportional to the production and pull time is short.</p>	171
11.40	<p>Dynamic simulation of the refrigerated compartment of a truck coupled with its refrigeration system</p> <p>A Rachek, V Sartre, J Bonjour</p> <p><u>Question or discussion point from A Al-Sahhaf</u></p> <p>The Gosney and Olama correlation you used to estimate infiltration rate is applicable for large cold store room doorways. In the truck refrigerated compartment, the refrigeration unit is blowing air directly towards the door. How is this going to affect the results?</p> <p>Author's response</p> <p>The fans are turned off during the opening of the doorways.</p> <p><u>Question or discussion point from J Guilpart</u></p> <p>I have two questions, The first one is about the validity of Gosney correlation which could be OK for larger internal volumes, but which validity has to be proven for a truck. The second one is do you take into account the heat load due to the ventilation inside the body?</p> <p>Author's response</p> <ol style="list-style-type: none"> 1) An experimental study is presently in progress to check the validity of the correlation. 2) Yes the model is able to calculate the power absorbed by the fans. 	172
12.00	<p>Energy consumption reduction in marine refrigerated containers</p> <p>R Lawton, T Mynott, N Marshall</p> <p><u>Question or discussion point from Douglas Smith, Nanopore Ltd</u></p> <p>Given the low number of days per year a container is used, how can one justify the cost of improved insulation?</p> <p>Author's response</p> <p>The cost of the insulation need to be reduced still further and in the case of vacuum insulation confidence be provided into its longevity.</p> <p><u>Question or discussion point from Douglas Smith, Nanopore Ltd</u></p> <p>How can the role of leasing companies, (who want to minimize capital cost), be overcome to pay for more advanced containers?</p> <p>Author's response</p> <p>The leaser(which is usually a shipping company) must insist that the container has an insulation k value below a certain threshold</p>	231
12.20	<p>Influence of mass-flow injection ratio on an economised indirect multi-temperature transport refrigeration system</p> <p>S Smyth, D Finn, B Brophy</p> <p><u>Question or discussion point from J Guilpart</u></p> <p>Your experimental results show a continuous variation of the injection ratios and a response of output variables (power, input, refrigeration capacities) somewhat un- continuous, with increase, plateau and increase again. Can you explain this observation?</p> <p>Author's response</p> <p>As the injection ratio is increased this will change the compressor characteristic, (pressure ratio). The corresponding changes in liquid line temperature and economiser saturation temperature result in a discontinuous temperature difference across the economiser heat exchanger leading to this trend.</p>	194
12.40	<p>Evaluation of secondary coolants in multi-temperature indirect refrigeration systems for transport applications</p> <p>S Smyth, D Finn, B Brophy</p>	196

Energy efficiency in food & pharmaceuticals

Tower Room, Chairman Don Cleland

11.00	<p>Reducing energy consumption in cold storage rooms J Evans, A Gigiel</p> <p><u>Question or discussion point from D Fitzmaurice, PED Refrigeration Consultants</u> You indicated a 35% reduction in heat gain through the insulated panels can be saved by increasing thickness from 125 to 200mm. Are there pay back figures if this measure is implemented at the construction stage?</p> <p>Author's response I don't have these to hand but they could be calculated easily enough.</p>	184
11.20	<p>Energy use across supermarket refrigeration JM Lawrence, D Gibson</p> <p><u>Question or discussion point from Don Cleland, Massey University</u> Has a comparison of PREDICT with a reduced number of timed defrosts been made?</p> <p>Author's response The number of defrosts with PREDICT averaged 1 per day, i.e. one third of the number that would have occurred with the normal timed defrost. The energy use if timed defrosts had been given with a time base of 24 hours would have been the same as with PREDICT. However, using PREDICT meant that when defrosts were needed after less than 24 hours, they were given; and when the cabinet could last more than 24 hours, the defrost was not given until necessary or until the time-out (27 hours or 30 hours depending on case type). Thus the energy savings would be the same with defrost timed at 1 per day but the danger to the food and continuing good operation of the cabinets would have been substantially increased.</p>	242
11.40	<p>Bread freezing and storage. Impact of process condition on energy demand A le Bail, T Dessev, V Jury, T Park and R Zuniga</p>	239
12.00	<p>Improving the energy efficiency of food refrigeration operations throughput the cold chain S James</p>	209
12.20	<p>The energy saving potential of ambient cooling systems S James, Y Senso, C James</p> <p><u>Question or discussion point from D Gibson, Dewpoint Consultants Ltd</u> Is not a problem of pie freezing the presence of an air layer between the filling and the crust, could not edible gunge be injected to fill the space & improve cooling time of the core?</p> <p>Author's response Yes, this is done in the case of pork pies.</p>	210
12.40	<p>Distribution of superchilled meat A Stevik, A Hemmingsen, E Indergård, T Nordtvedt</p> <p><u>Question or discussion point from Q.T Pham, University of New South Wales</u> What is the ice fraction in the superchilled meat?</p> <p>Author's Response The ice fraction meat treated like in the paper will be 10-15% dependent mainly on fat fraction.</p> <p><u>Question or discussion point from J Missenden, London South Bank University</u> Was there any physical difference (γ-mod.BHN) in superchilled & chilled meat to justify definitions of "frozen" & chilled- i.e. texture not temperature.</p> <p>Author's Response I m not sure if I understand this correctly, but there was not any difference between superchilled and chilled meat with regard to texture.</p> <p><u>Question or discussion point from T Suzuki, Tokyo University of Marine Science & Technology</u> How is the color change? In the case of pork, I think there is no problem but for beef and other red meat the color may change significantly in a superchilling state. Do you think the technique can be used for red meat?</p> <p>Author's Response We have tried it with red meat and, as you mention, the color was changed. The superchilled meat was less red.</p>	180

1.00 to 1.55 LUNCH, Dining Room

PAPERS SESSION 3 - TUESDAY 30TH MARCH 2010 (2.00 TO 4.00)

Innovation in process & equipment design

Diamond Room, Chairman Graeme Maidment

2.00	Improved efficiency and real time temperature monitoring in the food supply chain G Ólafsdóttir, S Bogason, C Colmer, M Eden, T Hafliðason, M Kück	253
2.20	Packaged ammonia chillers in the cold chain R Lamb, A Pearson <u>Question or discussion point from Z Tamainot-Telto, University of Warwick.</u> The amount of ammonia loaded in the system, could you give us a figure? Author's response The volume of refrigerant depends on the chiller size but is typically around 0.1kg/kW for water cooled chillers and 0.3kg/kW for air cooled based on standard chilled water conditions cooling from +12°C to +6°C. <u>Question or discussion point from A Gigiel, CCC Consultants</u> How is the cooling distributed from the container to the cold store or the application and what is the energy benefit for this? Author's response Cooling is distributed through a secondary chilled fluid (e.g. water or glycol). The key benefit is the reduced refrigerant volume and containment of ammonia to within the chiller. Compared to similar sized HFC chillers, the energy saving is around 20%.	247
2.40	Potential interest of electric field during food freezing; a review of electrofreezing A Le-Bail, M Orłowska, M Havet	240
3.00	Air cycle combined heating and cooling for the food industry A Foster, T Brown, A Gigiel, J Evans <u>Question or discussion point from S. Ditchev, Klimex</u> What is the relative humidity of air after the drier? This parameter is very important for maintenance of the expander? Author's response The minimum dew point measured after the drier was about -40C. The dew point was higher at start-up, as a higher flow rate went through the dryer. We were unable to avoid higher dew points in the system than the minimum temperature and, therefore, there must have been ice developed at the expander. We minimised this by drying the system before turning it on and using the dryer to reduce the dew point of the air entering the system. As ice was a concern to us we measured pressure difference across the two heat exchangers which were likely to ice up. We never measured any pressure drop that indicated icing, even after running at expander temperature below -100C for over 4 hours. I think the reason for this is that air has been dried enough such that the water quantity was small and that very low temperature ice does not stick to surfaces in the way that higher temperature ice does. Also, the military specification expander we used with titanium wheels was very robust.	185
3.20	The use of NH ₃ and CO ₂ heat pumps in food processing plants with cold storage facilities K Visser <u>Question or discussion point from S F Pearson, Star Refrigeration</u> What compressors are you using from the heat pumps? Author's response The heat pump calculations are based on Dorin CO ₂ compressors and Sabroe High Pressure HPO/HPC Ammonia compressors. The Ammonia compressors have a condensing temperature of +73 deg C and can therefore deliver hot water at a temperature of +68 deg C. To get +85 deg C water supplementary gas heating is required to lift the 68 deg C exit temperature to + 85 deg C.	190
3.40	Feasibility of using vascular perfusion chilling for red meat carcasses T Brown, J Evans <u>Question or discussion point from A Gigiel, CCC Consultants</u> Was water waste a problem? Author's response The experimental process discarded the perfusate after pumping it through a single carcass, which on a commercial scale would result in considerable effluent. In considering whether	186

	<p>the perfusate could be re-used for multiple carcasses, no bacteria were detected in the samples of perfusate collected as they left the carcass, but it might not be wise to rely on this as bacterial loads could conceivably build up and cross-contaminate. The perfusate could be subjected to a decontamination treatment as part of a re-circulation system but this would need to be carefully tested and monitored. If re-use of perfusate was found to be unacceptable, a cost-benefit analysis for perfusion would need to include disposal of effluent</p> <p><u>Question or discussion point from A Gigiel, CCC Consultants</u> Can't brine curing be combined with cooling? Author's response Several suggestions have previously been made to the author, including using brines, flavoured perfusates, sugar solutions etc. Assuming the ingredients in the perfusate were allowable as additives such suggestions could be possible, although the increasing cost of the perfusate would tend to further favour re-circulation to multiple carcasses - something which would require further study as described in the previous answer.</p> <p><u>Question or discussion from S Ditcher, Klimex</u> It is possible to explain the experiment for the determining the weight of carcass after the chilling? Author's response The abattoir weighing scales (attached to a section of overhead rail on which the carcasses were hung by previously tarred hooks) were used for all carcass weight measurements. For the measurements taken after chilling the carcasses were taken from the chill room and returned along the rail to the weighing scale.</p>	
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Advances in commercial refrigeration

Chadwick Room, Chairman Guy Hundy

2.00	<p>Ecodesign of refrigeration products S Mudgal, J Bain, M Liput <u>Question or discussion point from S Tassou, Brunel University</u> Does data refer to all member countries? Author's response The market data on stock and sales refers to EU-27.</p> <p><u>Question or discussion point from Mark Worrall, Nottingham University</u> Who are the stakeholders? Author's response These include industry associations, individual companies, NGOs and experts, for example.</p> <p><u>Question or discussion point from D Fitzmaurice, PED Refrigeration Consultants</u> How did you estimate the annual energy consumption figures used in the report? Author's response Data was taken from a number of sources including stakeholders. The website and report states the assumptions made.</p> <p><u>Question or discussion point from G Hundy</u> Has the scheme considered the UK energy technology list, particularly for chillers and air cooled condensing units? Author's response Yes, it has – these are discussed in Task 1.</p>	200
2.20	<p>Theoretical evaluation of integrated systems for refrigeration and air conditioning in supermarkets L Cecchinato, M Corradi, E Fornasieri, S Minetto <u>Question or discussion point from M Axell, SP Technical Research.</u> Have you taken in to account the infiltration of outdoor air in the building model? It will strongly influence heating demand, need for cooling, dehumidification and refrigeration load. Author's Response No air infiltration was considered in the conditioned areas. Only semi-exterior or unconditioned spaces are subjected to air infiltration.</p>	202

	<p><u>Question or discussion point from M Axell, SP Technical Research.</u> Has the variation in indoor climate been the same? Author's response The same indoor climate was assumed for the analysed systems</p> <p><u>Question or discussion point from M Lawrence, JTL systems.</u> What temperature was being used as condensing temperature for the CO₂ in the cascade system? Did this compromise the evaporating temperature used for the HT system? Are there problems with the pressure equipment directive requirements? Author's response The cascade R744 system condensation temperature was assumed to be -7°C, being -10°C the evaporation temperature for the MT units. The evaporation temperature of the MT unit was kept constant for all the proposed solutions, being determined by the display cases design. The CO₂ units need to be designed to meet the standards requirements, as well as the HFC ones.</p> <p><u>Question or discussion point from R Islam, Austral Refrigeration.</u> The integrations seem to add lots of complexity in the engineering systems. The cost could be quite significant compared to the energy savings mentioned. Have any cost analysis has been done? Author's response Our analysis does not contain economic considerations since our aim was to provide an energy evaluation of integrated HVAC and refrigeration systems. We hope that the paper can be a decision tool for supermarket consultants and chain owners. They can have an easier access to updated plant/units costs than we have and consequently deduce accurate payback times (based also on country labour, material and energy costs and taxations).</p> <p><u>Question or discussion point from R Islam, Austral Refrigeration</u> What adjustment has been made in comparing the Singapore and Stockholm in relation to the mode of the store HVAC. Singapore would need building cooling where as Stockholm would need heating? Author's response The heating and cooling loads were of course very different in Stockholm and Singapore. The units were sized to meet the actual requirements of each climatic condition. Not to influence the overall energy performance, the same compressor efficiency was assumed for all the climates. In the case of Stockholm, not to oversize the heat pump, an additional condensing boiler was considered, with 1.1 efficiency.</p>	
2.40	<p>Integration of CO₂ refrigeration and trigeneration systems for supermarket applications IN Suamir, S Tassou, A Hadaway, D Marriott <u>Question or discussion point from D Fitzmaurice, PED Refrigeration Consultants</u> The projected saving are against a conventional R.404A refrigeration system. With so much focus on optimizing existing conventional refrigeration system, what effect would this have on the relative savings? Author's response Somehow, if optimisation of conventional R-404A system could improve its performance, it would certainly reduce the relative savings of the proposed integration of CO₂ refrigeration and trigeneration system. However, the proposed integration system can still be optimised to obtain a better energy savings (see response of the question from I Chaer).</p> <p><u>Question or discussion point from S El Harch, Aleaf Refrigeration</u> Are you considering using exergy efficiency of the system you have mentioned in order to provide a more accurate figure of the system efficiency? Author's response Re: No, we are not considering exergy efficiency. We modelled the energy performance of the system using first law efficiency.</p> <p><u>Question or discussion point from I Chaer, London South Bank University</u> How will you optimise the system to achieve the expected fuel energy saving ratio over 30% as shown on the slide? Author's response The expected fuel energy saving ratio can be achieved by the following optimisation:</p>	203

	<ul style="list-style-type: none"> - Improving the trigeneration efficiency with utilisation of higher electrical efficiency CHP and better COP of the absorption chiller; - System sizing to match the real application in the supermarket; <p>Expanding the utilisation of cooling from trigeneration for air conditioning in the summer time.</p>	
3.00	<p>A R744 transcritical system with heat recovery for a supermarket - a case study I Colombo, L Jordan, G Maidment, I Chaer, J Missenden <u>Question or discussion point from M. Orlandi, Epta</u> How much was the amount of heat reclaim in the assessing CCP'S? Author's response According to Figure 3 left of conference paper, at optimal pressure 80 bar, the HE1 can reclaim 50 kW of heat from 70C to 95C and HE2 reclaim 170 kW from 25C to 50C.</p> <p><u>Question or discussion point from Y Ge, Brunel University</u> When heat reclaim is used in high pressure side the overall COP is largely increased. How was the overall COP calculated when heat reclaim was applied? Author's response The overall COP at 80 bar including the heat reclaim is equal to 1.8 and 4.7 without.</p> <p><u>Question or discussion point from D Fitzmaurice, PED Refrigeration Consultants</u> The CO2 system you used incorporates heat recovery, does the reference R404A system also have heat recovery? Author's response It is possible and it has been applied before but the discharge temperature of CO2 system is higher than R404a systems</p> <p><u>Question or discussion point from M Worall Nottingham University</u> In a transcritical system pressure and temperature are independent. The discharge temperature of 130° seems high compared with the pressure of about 80bar? Is COP optimised because there is an optimal discharge pressure for a given gas cooler outlet temperature? Author's response There is a combination of high Suction Liquid Heat exchanger after the evaporators and before the transcritical compressor that increase the superheat in order to get high discharge temperature after the compression of the refrigerant.</p>	206
3.20	<p>A Hadawey, S Tassou, IN Suamir, H Jouhara Performance optimization of a secondary refrigerant display cabinet using tests and CFD modeling A Hadawey, S Tassou, IN Suamir, H Jouhara <u>Question or discussion point from Anon London South Bank University</u> Your DAG velocities seem relatively low in compression with cabinets on the market, (JC 0.4 M/s) Please can you comment? Author's Response The velocity values presented in the paper are presenting the average velocity variation at the air curtain outlet.</p> <p><u>Question or discussion point from Anon London South Bank University</u> How did you model the real panel air flow? Author's Response A Porous Jump Model was used to model the flow from the back panel. Experimental work was done to establish the inputs to the CFD model as a function of the perforation rate.</p> <p><u>Question or discussion point from M Axell, SP Technical Research</u> What type of velocity sensor have you used to validate the CFD model and what is the estimated accuracy of the measurements for the low velocities in the air curtain? Author's Response Hot-wire velocity meter was used for velocity measurements with the following specifications: Range 0-50 m/sec, Accuracy +/- 3% of reading, Resolution 0.01 m/s</p> <p><u>Question or discussion point from R Islam, Austral Refrigeration</u> How the CFD optimization on air curtain would be different if the evaporator is for a DX instead of the secondary refrigerant evaporator?</p>	214

	<p>Author's Response Based on the output of the CFD model including air-off temperature and mass flow rate, the refrigeration system can be designed. However, there will be no difference on the CFD optimization if the evaporator is for DX instead of secondary refrigerant evaporator.</p> <p><u>Question or discussion point from R Islam, Austral Refrigeration</u> Has there been any comparison of the estimated heat loads against measured heat load? Author's Response Direct measurements of the air-off & on temperature and relative humidity were considered to evaluate the sensible and latent parts of the display cabinet total cooling load. Table 1, page3 shows a comparison of the 2D CFD model cooling load output with the calculated one.</p> <p><u>Question or discussion point from D Cleland, Massey University</u> Did you do any direct measurements at the air infiltration rate, (eg by trace gas dispersion)? Author's Response No.</p>	
3.40	<p>Reducing the wastage of fresh fruit and vegetables by consumers N Hipps, D Johnson, S Hails, J Evans</p>	256

Food quality, safety and microbiology

Tower Room, Chairman Silvia Estrada Flores

2.00	<p>Superchilling, ice fraction and quality A Stevik, A Hemmingsen, A Duun, H Walnum, T Nordtvedt <u>Question or discussion point from O Laguere, Cemagref</u> How long does it takes between the end of chilling and the measurement of ice fraction? I wonder if there is a melting of ice during this time which leads to an error of measurement? Author's response In this case the measurement was taken immediately after the chilling (10 sec)</p> <p><u>Question or discussion point from B Margeirsson, University of Iceland</u> Is it possible that the more even, (more precise) ice fraction of the salmon could be explained by the fact that it's fat content (fat ratio) is higher than for chicken? Author's response No, the problem is that the chicken samples used were more uneven in size.</p> <p><u>Question or discussion point from John Bowater, FJB Systems.</u> What is the packaging used over the whole process? Author's response We used vacuum packed polyetelen for the samples.</p> <p><u>Question or discussion point from J Evans London, South Bank University</u> In the task panel test did the panel just score the sample or did they supply any information on differences indentified? Author's response The panel just scored the sample.</p>	181
2.20	<p>Experimental study on vacuum freeze-drying of hylocereus undatus T Zou, S Ma, B Liu, X Yi</p>	197
2.40	<p>The effect of freezing and end cooking temperature on the eating quality of beef steaks C James, D Briggs, S James</p>	211
3.00	<p>Paper withdrawn</p>	
3.20	<p>Guaranteeing food quality in the food chain for imported meat products J Bowater</p>	254
3.40	<p>Regression equations for heat load and weight loss during beef chilling QT Pham , F Trujillo , L. Davey, N. McPhail <u>Question or discussion point from A Le Bail ONIRIS</u> A_w function is established in steady state. Your case is transient heat and mass transferred. Could this explain the discrepancy on mass losses? Author's response This could but the presence and surface distribution of liquids on surface of the carcass plays a bigger role.</p>	168

	<p><u>Question or discussion point from J Rabi, Cemagref</u> With respect to the model equations implemented in the FEM solver what were: (A) the initial conditions and (B) the day conditions, (connective and radiative heat transfer included.) Author's response (A) They come from the previous setup(from the previous operation) (B) Connective → CFD model implemented in 3D (C) Radiative → assume value from the emissivity</p> <p><u>Question or discussion point from B Margeirsson, University of Iceland</u> Would it have been possible to put °M the thermocouples earlier in the process? Author's response It's not really practical in the industrial operation. We would not be allowed to work in the slaughter / evisceration area.</p> <p><u>Question or discussion point from O Laguerre, Cemagref</u> What does it mean "Monte Carlo" simulation? Will you take into account "random variables" in your model? Author's response Monte Carlo" simulation involves randomizing the input parameters and carrying out a large number of calculations to obtain a realistic scenario.</p> <p><u>Question or discussion point from G Cavalier, Cemafroid</u> The conclusion says that experimental results agree with model results while a difference of more than 20% is underlined for weight difference of some per cent(_10%) it seem not coherent? Author's response We can explain the difference because the initial heat load during the first 15 minutes was not measured. Simulation showed that this would result in a difference of 16%. The rest is due to heat radiation from the leg to the ceiling which was not captured.</p>	
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4.00 to 4.25 COFFEE BREAK, Dining Room and Diamond Room

PAPERS SESSION 4 - TUESDAY 30TH MARCH 2010 (4.30 TO 6.10)

Innovation in storage & transportation

Diamond Room, Chairman Savvas Tassou

4.30	<p>Developments in active and passive refrigerated transportation for the pharmaceutical industry M Miller, A Mistry, R Lawton, T Mynott <u>Question or discussion point from A Sharp, Transport Studies Consultancy</u> You have described studies of re-usable thermal containers? Do you also have experience with testing smaller products? Author's response Yes, we have carried out temperature trials on smaller units, but they have not been covered in this paper.</p> <p><u>Question or discussion point from A Hadaway, Brunel University</u> The author's presented details of transportation sterilisation, any other data are available with regards to the power consumption as a result of using PCM? Author's response This was not requested by our clients for these particular products. However passive cooling systems do not have any heavy mechanical refrigeration machinery, therefore making the whole system lighter. This would save fuel for the vehicles transporting these products.</p>	232
4.50	<p>The potential for super-cooled storage of vegetables and fruits C James, V Seignemartin, N Salaun, S Costa, B Nanthieras and S James</p>	208
5.10	<p>Air leakage and heat leakage in insulated road transport equipment L Lukasse, M Staal <u>Question or discussion point J Guilpart</u> It is not a question, it is first a remark and a suggestion. I fully agree with the previous remark,</p>	216

	breathing of a body due to on- off of the refrigeration machine is very dependant of the air volume inside the body. Experiment on empty bodies could be biased compared to reality with full bodies. My suggestion, the frost deposition rate could be a very good indicator of the air tightness in road conditions. Author's response Good suggestion. Thanks a lot	
5.30	Experimental evaluation of optical absorption coefficient of insulated vehicle sandwich panel at the sun radiation G Panozzo, A Dragano, S Rossi, M Franceschi, P Bison	218
5.50	Modeling and experimental investigation of a transportation refrigeration system J Mun, K Choi, M Rifaldi, J Oh,	188

Modelling & predictive tools

Chadwick Room, Chairman Alan Foster

4.30	A model to evaluate refrigerated cabinet designs for energy efficiency R Love, D Cleland <u>Question or discussion point from J Rabi, Cemagraf</u> How does the model account for the number of products, (cans), inside the cabinet? Does it assume that the cabinet is always fully loaded? Authors response Each product items (can) is explicitly modelled by an ordinary differential equation (ODE) to predict the change in temperature based on a energy balance including heat transfer with the surrounding air flows. While standard performance test involve a cabinet full with cans, the model allows flexible selection of which cans in the array across the cabinet exist or not. <u>Question or discussion point from D Gibson, Dewpoint Consultants</u> Does "QUASI" steady state mean steady over a time step? Author's response Yes, quasi-steady-state means that the state of a variable is constant for a time step but variable between time steps (usually the variable is assumed to reach equilibrium rapidly).For example , the compressor is assumed to instantaneously reach operating speed so the mass flow of refrigerant is calculated algebraically as a function of suction and discharge conditions . <u>Question or discussion point from Mike Lawrence, JTL Systems</u> I have a feeling of déjà vie. I had to advise on the same problem - I think to satisfy the requirements of the same franchiser. I found the energy loss by the fan motor and the lights within the cabinet to be very important. An EC motor on the fan and turning the internal lights off were important contribution as well as larger evaporator and a larger condenser. The requirement was very tight in terms of pull down time and acceptable variations in product temperature in the case. Author's response Yes, these were the sort of issues the model was used to address and you have described some of the solutions ultimately implemented. <u>Question or discussion point from A Al-Sahhaf.</u> With the existing configuration, where the refrigeration unit is located at the top, there would be a large amount of spilled and infiltrated air through the cabinet when the door is opened? Author's response The model can be configured for both a top or bottom mounted refrigeration unit. Yes, if the door is opened then air will spill out. The standard performance test we were concerned with did not involve door openings so the model reported in this paper does not take into account door openings.	191
4.50	Annex 31: Advanced modeling and tools for analysis of energy use in supermarket systems J Arias, P Lundqvist, S Sawalha, M Axell	192
5.10	An interactive refrigeration system simulator software I Eames, T Brown, G Maidment, J Missenden, J Evans, M Swain and S James	246
5.30	Performance evaluation and design optimization of refrigerated display cabinets through fluid dynamic analysis G Artico, S Mousset, D Fortini	205

Innovative technologies for process equipment design

Tower Room, Chairman Judith Evans

4.30	<p>Generic data for the performance of alternative insulation systems measured over the temperature range -160 to +20°C B Crunkhorn, P McDonald <u>Question or discussion point from Guy Hundy, AlephZero</u> Where the thermal conductivity is referred to a temperature, how does this relate to the temperature difference across the insulation panel, particularly in an application where low temperature fluids are stored at ambient conditions? Author's response The thermal conductivity is measured with a temperature difference of +/- 15°C across the sample so that for a measurement at a mean measurement temperature of -20°C the surface temperatures of the sample would be -5 and - 35 °C.</p> <p><u>Question or discussion point from FJ Bowater, FJB systems</u> Have you carried out any investigations into water absorption into different insulation core materials? This is a major problem where cold store ceilings absorb water and ice resulting in some 10 to 20 time weight increase resulting in ceiling collapse. Author's response We have done work in this area in response to specific requests from insulation producers/suppliers</p> <p><u>Question or discussion point from G Cavalier, Cemafroid</u> The presentation shows a linear correlation between λ and the density of PU foams. We can find on the market PU Foams with a higher λ and higher density than others. What are the PU foams referred to in the graph? Author's response The graph has a linear temperature scale versus a logarithmic thermal conductivity scale. This enables us to present a wide range of materials on a single page. PU materials of different densities are included and the data in Figure 5 gives an indication of how the thermal conductivity of a PU foam varies with density</p>	248
4.50	<p>Optimal configuration and energy conservation of condensers based on part load J Zhang, Y Xu <u>Question or discussion point from Mark Worall, Nottingham University</u> If the condenser is at 30% load shouldn't compressor load be reduced? Author's response The condenser load comes from compressor. When the condenser is at 30% load, it means that the heat load inside cold store is low and running compressors are fewer (that is, compressor load has been reduced). Most plants deploy oversize (excessive) compressors and condensers in China. People pay attention to reduce compressor load but not to reduce condenser load.</p>	193
5.10	<p>Development of solar thermal heating and cooling systems using the jet pump cycle R Fenton, S Knowles, I Eames and G Maidment</p>	258
5.30	<p>A review of "pumpless" absorption refrigeration cycles A Paurine, G Maidment, I Eames, J Missenden <u>Question or discussion point from Mark Worall, Nottingham University</u> What drives the circulation? Author's response Low grade heat</p> <p><u>Question or discussion point from R Fenton, Industrial Design Consultancy Ltd</u> What is the pressure difference between absorber and generator? Author's response It varies depending on the operating temperatures (in the range of 4 - 7kPa)</p> <p><u>Question or discussion point from R Lawton, CRT</u> Can you outline to us the problems you experienced with the materials? Author's response There were lots of problems I experienced and most critical one was that, most materials with</p>	233

	good thermal conductivity such as copper and aluminium for constructing heat exchangers are easily corroded by LiBr-Water solution and especially with high temperatures involved.	
5.50	Waste heat driven MAC Z Tamainot-Telto, S Metcalf, R Critoph	260

6.10 CLOSE OF DAY 2

6.30 to 7.30 Commission Meetings

D2 refrigerated transport commission in the Chadwick Room

7.15 PRE DINNER RECEPTION, sponsored by Nanopore Insulation Ltd in the New Senior Common Room

8.00 CONFERENCE DINNER, Dining Room

DAY 3 – WEDNESDAY 31ST MARCH 2010

Short courses 9.30 to 12.30
<p>Mathematical modeling Tower Room, Chairman Bart Nicolai Speakers: Don Cleland, Alan Foster, Annemie Geeraerd, Bart Nicolai, Bart Nicolai <u>Question or discussion point from J Thompson, Parson Brinckerhoff</u> To what extent is it worth writing a one off code tailored to you problem rather than relying on other more general commercial code Author's response Recommend commercial code in most cases.</p>
<p>Temperature control and energy efficiency in the cold chain Chadwick Room, Chairman Silvia Estrada-Flores Speakers: Don Cleland, Silvia Estrada-Flores, Judith Evans, Stephen James David Pearson <u>Question or discussion point from Monica Axell, Sp Technical Research</u> The heat loads in the cold store, can you express the impact in % from the different loads? Author's response Every coldstore is different. However, air infiltration can be as much as 50% of the total heat load, fan power can be up to 20% and envelope transmission is often the largest other load. In some circumstances, lighting, defrost and product loads can be significant but this should be the exception rather than the norm.</p>
<p>Alternative technologies review and action workshop Diamond Room, Chairman Graeme Maidment Speakers: Andrew Giegel, Neil Mathur, Zachary Tamainot-Telto, Savvas Tassou, Neil Wilson</p>

12.30 to 1.20 LUNCH, Dining Room

1.25 PLENARY SESSION IN DIAMOND ROOM

Chairman Graeme Maidment

1.25 Towards a sustainable cold chain from D Cleland, Head of the School of Engineering and Advanced Technology Massey University

1.55 Introduction to the Co-operative Research Programme, Biological Resource Management for Sustainable Agricultural Systems from Janet Schofield, Programme Secretary for Organisation Economic Co-operation and Development

PAPER SESSION 5 – WEDNESDAY 31ST MARCH 2010 (2.10 TO 3.50)

Sustainable retail refrigeration

Diamond Room, Chairman Radim Cermak

2.10	Evaluation of energy savings by heat recovery from refrigeration plants in supermarkets G Cortella, O Saro <u>Question or discussion point from N Espinoza, University of Manchester</u> The paper showed results when energy was recovered in one portion of the mall analyzed. What are the consequences if the whole mall is considered? Author's response Only one position of the mall was considered because it contained a heat pump loop that can be analyzed. Just this energy recovered is sufficient to be used in the whole mall. Currently studies are being done considering the whole mall scenario; all depends on the amount of energy that can actually be recovered.	176
2.30	Concurrent refrigeration passive defrost to control meat surface temperature in open refrigerated display cabinet R Islam	177
2.50	Performance of retail and commercial refrigeration systems J Evans, M Swain	183
3.10	Controlling noise of refrigeration equipment in neighbourhood retail S Lamy, P Poysat	198
3.30	Vertical display cabinets with and without doors - a comparison of measurement in laboratory and in supermarket U Lindberg, M Axell, P Fahlén	219

Modelling & predictive tools

Chadwick Room, Chairman Tuan Pham

2.10	Prediction of thermal conductivity for frozen foods with air voids J Wang, J Carson, J Willix, M North, D Cleland	173
2.30	Temperature prediction in domestic refrigerator: determinist and stochastic approaches O Laguerre, D Flick <u>Question or discussion point from B Margeirsson, University of Iceland</u> You mentioned that the whole cold chain will be taken into account in your model, (in future work). Will different interfaces with accompanying thermal abuse of the chain also be included? Author's response Yes, particularly, the interface (transport by consumer) and the last two steps of the cold chain (display cabinet and domestic refrigerator) which are often critical in term of temperature abuse.	178
2.50	Investigation of heat pump seasonal efficiency using a computation model G Hundy, E Winandy	234
3.10	Novel design and performance of domestic refrigerators C Marques, G Maidment, G Davies, J Evans, I Wood <u>Question or discussion point from Guy Hundy, AlephZero</u> Cycling losses could be significant if the unit is only running for 10% of the time. Also is reliability impaired? Author's response The theoretical model presented established that larger compressors displacements are more efficient resulting in a refrigerator energy reduction of 17% by increasing compressor displacement from 4cc to 8cc. As the compressor displacement increases the run time of the appliance decreases, i.e. for the 8cc compressor the run time is 10%. In practice larger compressors would only be more efficient if their excess cooling capacity is used, thus to achieve this, a phase change material (PCM) would be employed to store compressor cooling capacity. The PCM associated with the evaporator would increase the on and off cycles of the compressor improving its reliability and overall it would increase refrigerator autonomy with reduced energy consumption. <u>Question or discussion point from D Cleland, Massey University</u> When the compressor was changed from 4cc to 8cc was this for the same evaporator and condenser? If so, was the effect on evaporating and condensing temperature taken into	229

	<p>account? Author's response The theoretical model assumed that the evaporating and condensing temperatures would be the same for all displacement compressors. In the future experimental validation the evaporator and condenser would need to be sized when the compressor displacement is changed in order to obtain the same evaporating and condensing temperatures. In case of space constrains to fit different evaporators/condensers due to rigid refrigerator dimensions the effect on evaporating and condensing temperature will be taken into account in the compressor displacement effect analysis.</p>	
3.30	<p>Optimization of chicory root cold store humidification system using computational fluid dynamics M Delele, A Schenk, B Nicolai, P Verboven <u>Question or discussion point from A Sharp, Transport Studies Consultancy</u> In a sealed room, if you add water, the water will ultimately be deposited in the evaporator coils. Wouldn't it be better to use a larger evaporator and to control RH? Author's response Most chicory cool rooms are equipped with a direct expansion system which operates at a Delta T of 5-6°C. A flooded evaporator system or a larger evaporator and RH control would indeed reduce the need for humidification. Changing the deflectors was a much cheaper option, however.</p> <p><u>Question or discussion point from D Cleland, Massey University</u> Did they consider a RH controller rather than timed humidification? Author's response No, only timed humidification was considered. After optimisation the reduction in ice formation and the uniformity of the RH were quite good, though.</p>	250

Innovative technologies for process & equipment design

Tower Room, Chairman Andrew Gigiel

2.10	<p>Development of a micro cooling probe for brain mapping S Mahmoud, R Al-Dadah, D Aspinwall, S Soo</p>	221
2.30	<p>Groundwater system with heat pumps saves 70% of energy H Winther, M Klootwijk</p>	238
2.50	<p>District heating, district cooling and desalination using ammonia heat pumps D Pearson</p>	255
3.10	<p>Alternative geothermal heating sources, heat pumps and their application J Thompson, G Maidment</p>	235
3.30	<p>Numerical analysis of a plate fin and tube evaporator using the natural refrigerant CO₂ J Shilliday, S Tassou</p>	259

3.50 to 4.10 COFFEE BREAK, Dining Room and Diamond Room

PAPER SESSION 6 – WEDNESDAY 31ST MARCH 2010 (4.15 TO 5.15)

Sustainable retail refrigeration

Diamond Room, Chairman Issa Chaer

4.15	<p>Energy-efficient laminar flow heat exchangers indirectly cooled display cabinets - reduced use of energy and improved temperature quality of the provisions C Haglund Stignor, M Axell</p>	220
4.35	<p>Performance evaluation and control optimization of a CO₂ booster refrigeration system in supermarket Y Ge, S Tassou</p>	237
4.55	<p>Development of a design tool for recirculated air curtains used on retail display cabinets E Hammond, J Evans, A Foster <u>Question or discussion point from A Hadawey, Brunel University</u> In real situations of a display cabinet there is a back panel flow shelves and product. Do you believe that your results are applicable to real working display cabinets? Author's response This study aimed to analyse simple refrigerated air curtains sealing open fronted cavities but</p>	252

	<p>it is likely that the technique described could be applied to conventional display cabinets if suitable factors were added to allow for the supporting effect of back panel flow. However, despite having a stabilising effect on the air curtain and enabling some energy saving, back panel flow does prohibit good temperature control of stored product. It therefore follows that a chute shelf display cabinet, which could be designed using the data presented in this report, may be a better solution to the problem and so extending the model would not be useful. Shelves and product loading would be more complex to allow for due to the possible variations capable of causing either disturbances or support for the curtain but provided the curtain was designed to be self supporting in front of the product and shelves, the performance of the curtain would be independent of product loading.</p>	
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Developments in packaging

Chadwick Room, Chairman Robert Heap

4.15	<p>Proposal for determining the thermal rating of insulated packages intended for the transport of perishables A Sharp, E Orszulok <u>Question or discussion point from Anon</u> Do we know enough if we are only know U? Author's response It is true that the U-value is not the whole story, but it provides a basis for choosing one package over another <u>Question or discussion point from A Kacimi, Sofrigam</u> What were the insulated materials of the insulated packaging used in the tests(PU, EPS, XPs....)? The thickness of the walls and the type and the mass of the coolant, (cold source), used? What was the uncertainty for each method? Author's response We measured the characteristics of many different types of packaging, buy our main interest was in foil-faced corrugated fibre board packages. We found box in box designs were as effective as expanded polystyrene boxes of the same dimensions.</p>	236
4.35	<p>The rate of moisture sorption by packaging in the cold chain J Bronlund, D Cleland, S MacKay, T Elsten <u>Question or discussion point from T Pham, University of New South Wales</u> Would the heat of absorption have any significant effect on the cooling of the product? Author's response No, generally the heat of sorption has a negligible long-term effect on product cooling. This is because the packaging mass is usually small compared with the product mass and the change in moisture content is relatively small, so the quantity of heat of sorption is small.</p>	224
4.55	<p>Low emissivity food packaging for more efficient refrigeration and carbon saving G Davies, G Maidment, D Man, D Andrews, N Jia, M Hutchins <u>Question or discussion point from T Pham, University of New South Wales</u> Your results apply only to open top freezer cabinets. What percentage of freezer cabinets would belong to this type? Author's response Open display type freezer cabinets are found in practically all supermarkets in the UK. Based on the results of a recent survey, it is estimated that of the order of 15% of freezers currently used in supermarkets are "well" type (i.e. open display) freezer cabinets. <u>Question or discussion point from Robert Heap</u> Would there still be some benefit if the cabinets had transparent covers, as some do? Author's response Glass covers would reduce radiant heat transfer to the food; however, supermarkets wish to avoid the use of covers or doors on freezer cabinets as it restricts customers' access to the products. By using low emissivity packaging, supermarkets could display their frozen food products in open display cabinets (as at present), but with greatly reduced radiant heat absorption. This would permit the freezer to be operated with a higher evaporator temperature (i.e. up to 10 K), with no loss in refrigeration performance with respect to the food, but resulting in reductions in energy use and carbon emissions of up to 30%. <u>Question or discussion point from Anon</u> Will you continue?</p>	228

	<p>Author's response</p> <p>Yes, we are planning to continue with the work. The results achieved to date indicate that the use of low emissivity packaging has great potential for substantially reducing energy use and carbon emissions during refrigerated food storage, and has already attracted considerable interest from industry.</p>	
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Carbon foot printing & assessment methodologies

Tower Room, Chairman Graeme Maidment

4.15	<p>Carbon footprint of ready-made chilled meals N Espinoza Orias, H Stichnothe, A Azapagic</p> <p><u>Question or discussion point from S Estrada Flores, Food Chain Intelligence</u></p> <p>I found your presentation very thought provoking. I wonder how the carbon footprint would vary if we have a vegetarian RTE instead of a meat-based meal?</p> <p>Author's response</p> <p>If the meat component in the ready meal recipe is replaced by any protein replacement product, the contribution of these products to the overall GHG emissions arising from the ready meal will depend on the origin of the replacement ingredient, the methodology used to calculate its carbon footprint and the rationale of meat replacement (similar protein content or similar mass):</p> <p>For example, Quorn (mycoprotein) has a carbon footprint of 2.3 kg CO₂-eq/kg and tofu has a carbon footprint of 2 kg CO₂-eq/kg (Broekema and Blonk, 2009). Compare these to meat from animals reared in the UK: chicken meat has a carbon footprint of 3.1 kg CO₂-eq/kg (intensive, indoor chicken) and lamb meat has a carbon footprint of 28 kg CO₂-eq/kg (intensive, lowland) (Wiltshire et al., 2009).</p> <p>If soya products are used as protein replacements, then it is necessary to evaluate if soya is produced in land that has undergone recent land use change or not, which is a methodological requirement from PAS 2050:2008. The emissions arising from land use change can increase significantly the carbon footprint of alternatives to meat.</p> <p>Vegetarian meals will have in general a relatively lower carbon footprint than meals containing meat ingredients. However, depending on the agricultural practices, some vegetables can have high carbon footprints. Compare the carbon footprint of the following vegetables (Wiltshire et al, 2009):</p> <table data-bbox="255 1153 1356 1366"> <tr> <td>Carrots (UK):</td> <td>0.35 kg CO₂-eq/kg</td> </tr> <tr> <td>Potato (UK):</td> <td>0.16 kg CO₂-eq/kg</td> </tr> <tr> <td>Organic potato (UK):</td> <td>0.12 kg CO₂-eq/kg</td> </tr> <tr> <td>Tomato (ES):</td> <td>1.80 kg CO₂-eq/kg</td> </tr> <tr> <td>Tomato, grown in oil heated glass house (UK):</td> <td>2.30 kg CO₂-eq/kg</td> </tr> <tr> <td>Tomato, grown in glass house using waste heat from other processes (UK):</td> <td>0.39 kg CO₂-eq/kg</td> </tr> </table> <p><i>References</i></p> <p>Roline Broekema and Hans Blonk. Milieukundige vergelijking van vleesvervangers. Blonk Milieuvadvis, Gouda, 2009.</p> <p>Jeremy Wiltshire, Sarah Wynn, James Clarke, Brian Chambers, Bruce Cottrill, Dan Drakes, Jason Gittins, Chris Nicholson, Kate Phillips, Rachel Thorman, Don Tiffin, Odelle Walke, Gary Tucker, Robin Thorn, Andrew Green, Anke Fendler, Adrian Williams, Pat Bellamy, Eric Audsley, Julia Chatterton, Dave Chadwick, Chris Foster. <i>Scenario building to test and inform the development of a BSI method for assessing greenhouse gas emissions from food</i>. Report to Defra, Project Reference Number: FO0404. ADAS, London, 2009.</p> <p><u>Question or discussion point from G Cavalier, Cemagref</u></p> <p>It should be important to give the uncertainty of the results because it can be very large. In the difference segments energy and F-gas are taken into account for carbon footprint calculations. What about the people working in the factories, there transport, the production installations on the buildings of the stores and storage and so on?</p> <p>Author's response</p> <p>The uncertainty analysis of the carbon footprint of a product is not a requirement prescribed by PAS 2050:2008. Technical uncertainty in the calculations shown in the present work has been reduced as much as possible through the use of primary data and modelling the complete life cycle of the ready meals. The variability of the primary data is accounted for by</p>	Carrots (UK):	0.35 kg CO ₂ -eq/kg	Potato (UK):	0.16 kg CO ₂ -eq/kg	Organic potato (UK):	0.12 kg CO ₂ -eq/kg	Tomato (ES):	1.80 kg CO ₂ -eq/kg	Tomato, grown in oil heated glass house (UK):	2.30 kg CO ₂ -eq/kg	Tomato, grown in glass house using waste heat from other processes (UK):	0.39 kg CO ₂ -eq/kg	241
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	<p>using average annual production data.</p> <p>Nevertheless, fair comparisons between products or production systems can be made when the final results and the uncertainty estimates are reported. In agricultural and food production systems factors such as country of origin of the ingredients, micro-climate, soil type, seasonality of the ingredients, agricultural practices, degree of mechanization, crop variety, animal breed, water scarcity do affect the variability of the outputs season by season, year by year. It is a complex exercise to capture how the variation in all these factors affects ultimately the uncertainty associated with the final ready-made chilled meal. In many cases, sufficient information will not be available or will not exist at all.</p> <p>By definition, the GHG emissions calculated using the PAS 2050:2008 methodology correspond only to the product system. The GHG emissions associated with employee transportation and administrative offices operation fall outside the product system boundaries. However, the GHG emissions associated with transport, storage and retail of raw materials, ingredients and the final product are included in the calculation of the ready meal carbon footprint.</p>	
4.35	Estimation of CO ₂ emission from the transportation process of mackerel in Japan M Watanabe, A Suzuki, H Komaki, K Osako, T Suzuki	179
4.55	Measurement and simulation of energy consumption of transport refrigeration equipments G Cavalier, A Stumpf	215

5.20 CLOSING SESSION

Diamond Room, Chairman Andy Pearson

- 5.20 Sustainable technology development and influencing policy from Andy Pearson, President Elect, Institute of Refrigeration

5.35 CONFERENCE ENDS

