THE INSTITUTE OF REFRIGERATION

Hydrocarbons in Commercial Refrigeration

by

Les King FInstR[1], Ian Garvey MInstR[2],

Additional contributors
Jane Gartshore FInstR[3], Stephen Benton FInstR[3]

[1] John Lewis Partnership
[2] Carter Retail Equipment Ltd
[3] Cool Concerns Ltd

(Session 2010-2011)

To be presented before the Institute of Refrigeration at
The Hilton Birmingham Metropole Hotel, NEC, Birmingham, West Midlands B40 1PP
On Thursday 3rd February 2011 at 5.45pm

This paper outlines the new design standard for refrigeration to all Waitrose new stores and major refits. It demonstrates how refrigeration integrates with building services and explains why hydrocarbon refrigerant was selected. The significant carbon and cost savings achieved through virtually total leakage elimination and improved store energy efficiency are quantified. This paper also shows how HC refrigerant has been safely applied in equipment ranging from display cabinets to chillers, and the procedures which have been developed so engineers can work safely on HC systems.

<u>Background</u>

All retailers need to reduce the environmental impact of their refrigeration systems. This paper demonstrates how substantial reductions can be made by moving away from traditional central plant systems to integral refrigeration systems integrated with the store building services. This concept has virtually eliminated refrigerant leakage and significantly reduced the overall energy consumption of the store, delivering substantial carbon benefits.

A major aim was to eliminate leakage of refrigerant. This not only reduces the direct impact of a leaking system on climate change, but also the indirect effect associated with increased energy consumption of a system running with insufficient charge. Therefore re designing central plant systems to use an alternative refrigerant with reduced global warming potential was not an option. The solution of using integralised, factory manufactured and tested systems was the most logical as the leak potential is inherently low and the range of suitable natural refrigerants is greater than that available for distributed systems.

Typically a conventional supermarket integralised refrigeration system negatively impacts on the internal environment through inherent noise generation and the need to locally reject heat from the refrigeration systems. This additional heat load within the store requires further energy, normally via mechanical cooling from the HVAC systems, to not only maintain a comfortable environment, but to also ensure the efficient operation of the cases.

These adverse impacts are significantly reduced by the replacement of the traditional air cooled condenser with that of a water cooled type. The heat rejected to the glycol treated water circuit can be readily reclaimed. The residual heat rejected to air provides further energy and environmental benefits.

The use of HC refrigerant was possible because of the small charge size in all internal refrigeration systems. All charge sizes are well below the maximum specified in the relevant standard.

The integrated refrigeration and building services solution

The new Waitrose refrigeration solution reduces the direct carbon emissions associated with refrigerant leakage and the indirect emissions through efficient use of energy within the store. These efficiencies, coupled with improved equipment reliability, maintain customer comfort levels, food quality and safety. This has been achieved by:

- Complete integration of the refrigeration and HVAC systems to utilise waste heat and cooling overspill from the refrigeration equipment, whilst maintaining capacity and efficiency;

- The use of small factory produced refrigeration systems with low refrigerant charge and minimal leakage potential.

The refrigeration and air conditioning systems use either R290 (propane) or R1270 (propene) rather than HFC refrigerants. Shop floor cabinets are all integral types either water or air cooled, or in some cases both. A water or water / glycol mix is used to remove 75% of the rejected heat from the display cabinets. The remaining 25% of heat is rejected to air at high level and distributed down the chilled aisles so the usual additional heating is not required.

The cold rooms are cooled using close coupled units with 100% of the heat rejected to water / glycol.

Chillers provide a water or water glycol mix at +18^{O}C, with a typical return at +24^{O}C. This temperature was selected to provide optimum performance of the integral cabinet and the chiller. When the ambient temperature is less than 16^{O}C the chillers run in “free cooling” mode - i.e. the compressors do not run, thus providing significant energy savings.

The refrigeration systems are integrated with the HVAC system, providing the following:

- Cold aisles are heated by the warm air rejected from the integral display cabinets;

- Cold air spillage from the cases is extracted at low level and circulated to areas of the store prone to overheating (cold air retrieval), thus eliminating the need for air conditioning in most areas;

- Heat is recovered from the return chilled water into the fresh air make up when the ambient is below 16^{O}C. The only space heating for the shop floor is for the door curtains, which use low pressure hot water.

(Diagram 1 shows a simple schematic of the system).

This refrigeration / HVAC design significantly reduces the store’s carbon footprint and its running costs and is quantified in the next section.

The design integrates tried and trusted technologies in an innovative way:

- All refrigeration systems are manufactured, tested, critically charged and commissioned in a factory environment, reducing:
    - installation time on site by two weeks

- individual refrigerant charge size and leak potential
- possibility of control set points being wrongly adjusted during commissioning or service;

- Integralised cabinets omit the need for complicated site installed refrigeration pipe work and the inherent leak potential, pressure drop and heat gain within the system;

- Water cooled integral display cases considerably reduce the heat and noise into the store, compared to traditional integrals;

- Hydrocarbon refrigerants increase the energy efficiency of the individual systems, typically between 10 and 20% - this is quantified in the following sections.

- Heat recovery is used to reduce the HVAC load without reducing the performance of the refrigeration systems.

To date, the John Lewis Partnership has 26 Waitrose stores now operating on a complete hydrocarbon integralised solution. This water-cooled / propane natural refrigerant system will be installed within all their Waitrose shops by 2020 and a programme of work is underway to achieve this.

Running cost savings

Following the trial in 2007 of the original 'hybrid' concept of integralised water-cooled refrigeration (based upon HFC refrigerant due to compressor availability), the solution has been developed to that which is outlined within this paper.

The data below comes from a recently completed refit of a Waitrose store.

Historic Energy Consumption	**Electricity (kWh)**	**Gas (kWh)**	**CO2te**
Date - w/c			
28/09/09	35,394	9,800	21.03
05/10/09	34,376	15,236	21.48
12/10/09	33,162	17,647	21.27
19/10/09	33,585	17,625	21.50
26/10/09	34,395	15,426	21.53
02/11/09	32,541	19,899	21.35
09/11/09	32,738	22,662	21.97
16/11/09	33,915	19,744	22.07
Total	**270,106**	**138,036**	**172.19**
Date - w/c			
27/09/2010	32,714	2,573	18.24
04/10/2010	38,269	4,681	21.64
11/10/2010	35,583	5,587	20.35
18/10/2010	31,771	11536	19.38
25/10/2010	31,385	9562	18.81
01/11/2010	32,971	7617	19.31
08/11/2010	30,152	7032	17.67
15/11/2010	29,589	10066	17.93
Total	**262,434**	**58,654**	**153.32**

Therefore, for the dataset provided, the energy consumed within the test project (excluding F-Gas leakage) is :-

Electricity	2.84%	Reduction
Gas	57.51%	Reduction
CO2te	**10.96%**	**Reduction**

The average leakage rate of HFC refrigerant across the Waitrose estate equates to approximately 336 CO2te per annum per branch (112.5 kg R404A). To date, within the test store, there has been zero HC refrigerant loss.

Via extrapolation, from the 8 week dataset to an annualised period we are able to conclude the following:

Traditional Centralised HFC Plant		**Integrated HC Water-cooled HVAC/ Refrigeration Solution**	
	CO2te		CO2te
Gas and Electricity	1,119.25	Gas and Electricity	996.61
F-Gas Leakage	336	Refriger-ant Leak-age	0
Total	**1,455.25**	**Total**	**996.61**

Therefore, we can conclude that the revised integrated solution of the store HVAC systems coupled with HC water-cooled, Integralised refrigeration is delivering circa **32%** CO2te reduction in overall carbon emissions as compared to the previous traditional refrigeration system.

Conversion factors for CO2te are taken from DEFRA[1] and are as follows :-

Electricity: 0.54284 -
Annex 3, Table 3c - Total GHG

Natural Gas : 0.18523 -
Annex 1, Table 1c - Total GHG

Global warming potentials have been taken from EN378-1:2008 Refrigerating systems and heat pumps - Safety and environmental requirements, part 1 (R404A GWP, 3260
R1270 and R290 GWP, 3)[2]

Other key advantages

This type of refrigeration installation is capital cost neutral compared to traditional building services systems and has additional revenue benefits. There are also other significant advantages to this refrigeration solution which have a positive impact on the business:

- Two weeks less installation time compared to centralised traditional plant installation.
- A reduction of first year service and maintenance costs of at least 44%. A greater reduction is anticipated through the lifetime of the equipment;
- Flexibility in the event of store changes and future refits;
- The simplicity of small Integralised systems, typical of domestic style refrigeration. These provide the benefit of simple control and less maintenance thus enhancing the reliability and efficiency of the cabinet;
- Minimal site installation and commissioning and less service and maintenance requirement. However, engineers do need additional training in safe handling of HCs, as described in the following section.

Application of hydrocarbon refrigerants

An important aspect of the use of hydrocarbon refrigerant is ensuring they are safely applied. To verify this a specialist external consultant was employed to identify applicable standards and examine each system model to validate compliance with the relevant standards.

Various hydrocarbon systems are used in the Waitrose stores. These include:

- Small plug in systems such as catering fridges and ice makers with a charge less than 150g;
- Integral display cases and serve over cabinets with a charge of up to 1.5 kg per individual circuit;
- Mono-bloc cold room systems with a charge up to 300 g;

- Split air conditioning systems.
- Water or glycol chillers with a charge of up to 10 kg per circuit.

There are various standards and regulations which cover the use of hydrocarbon refrigerants and they are listed below.

EN378

Maximum charge sizes and the practical limit for hydrocarbon refrigerants are specified in EN378[2]. This standard includes guidance for hydrocarbon refrigerant, which is summarised below for retail systems:

- Systems with a charge up to 150 g can be used in any location;

- Systems directly cooling a shop floor area (General occupancy- Class A as defined in EN378) must have a maximum charge of 1.5 kg, or 1 kg if sited below ground;

- The practical limit is 0.008 kg/m^3, so an individual circuit charge cannot exceed this if the refrigerant can leak into a human occupied space. This is not a consideration on the shop floor where a leak from an integral display cabinet would result in a concentration of HC well below the practical limit, but does apply to cold room systems for example;

- The maximum charge for the split air conditioning systems is specified in the equation
  $M = 2.5 \times LFL^{1.25} \times h \times \sqrt{A}$
  where LFL is the lower flammability level (kg/m^3), h is a factor for the height of the indoor unit (m) and A is the floor area (m^2).

The systems at Waitrose are all within these limits. EN378 is not harmonised to the ATEX directives (see below) but does direct you to EN60079 for electrical compliance. It cannot be assumed by complying solely with EN378 that an HC system is electrically safe.

ATEX (ATmosphères EXplosibles) and EN60079

Commercial refrigeration systems which use flammable gases have the potential to develop a flammable atmosphere around the equipment in the event of a leak and should therefore comply with ATEX 95 (equipment directive 94/9/EC)[3]. Testing should be carried out to determine whether sources of ignition on the system are within a flammable zone in the event of a leak, and if so these should be dealt with. A manufacturer can self certify that systems meet the Essential Safety Requirements of ATEX so notified body involvement is usually unnecessary.

EN60079[4] is harmonised with ATEX and has therefore been used as the basis for checking that the systems supplied to Waitrose are safe for use with HC refrigerants. There are three options for dealing with electrical devices (which are sources of ignition) that are located inside a potentially flammable zone:

- Relocate the device outside the potentially flammable area (preferred);

- Replace with a device rated for operation in a Zone 2 environment (Group II Category 3 as defined by ATEX);

- Segregate the device from the potentially flammable area (e.g. by using a suitable enclosure. An IP rating in its own right is not deemed sufficient protection for a source of ignition in a potentially flammable zone).

EN60079-10-1:2009 (Classification of areas – Explosive gas atmospheres) is used for checking the extent of the flammable zone in the event of a leak. It defines leak rates and the extent of a flammable volume. It enables a manufacturer to check whether sources of ignition are within a flammable zone and where sources of ignition can be safely located. The standard however is onerous and calculates conservative zones which in reality do not represent the extent of zones measured in actual leak simulation exercises. Test work has been carried out on a number of HC systems using leak simulation methods employing actual HC release and measurement of flammable zone extents to determine the requirement for Zone 2 compliant electrics. It should also be noted that mechanical sources of ignition such as fan blades in cowlings are also considered in this exercise.

Devices which are located inside a flammable zone (as determined above) could comply with IEC60079-15:2010 (Electrical apparatus for explosive gas atmospheres - Construction test & marking of type of protection "n" electrical apparatus). Part 15 only relates to one type of protection, there are numerous others with in the 60079 series of standards and these could also be adopted. Standard electrical components can be tested in line with the requirements of EN60079 to check compliance. The below types of protection are included within EN60079-15 and are outlined briefly (this list is not exhaustive):

1.Restricted-breathing enclosure "nR" – the enclosure construction and sealing is to a very high standard and testing rigorous. Normal IP rated enclosures and cable glands would not comply and the enclosure can only comply if the internal temperature increase is minimal so typically large numbers of contactors, relays or transformers render this protection type invalid.
2.Enclosed-break device "nC" – applies only to small enclosures not exceeding a free internal volume of 20 cm^3 (potential relays, current relays, thermostats etc), the device is tested to ensure that an internal ignition of a flammable mixture can be contained by the enclosure and not allow that ignition to propagate to the remainder of the mixture.
3.Hermetically sealed or sealed device "nC" – atmosphere cannot enter the device.

A number of compressor manufacturers have already had their potential and current relays tested and are compliant with EN60335-15 'Enclosed Break Device'. Small thermostats are also suitable for this testing regime and two manufacturers of such stats have complied and passed the enclosed break testing regime.

Zone 2 of NE (Negligible Extent)

There is technically no de minimis with regard to ATEX. However if it can be demonstrated that a flammable volume is below 0.1m^3 the zone can be classed as a Zone 2 of NE (Negligible Extent). The calculation for Zone 2 NE can be found in EN60079-10-1 and again is conservative, so high ventilation rates through an enclosure have to be achieved to satisfy the minimum Vz (flammable volume). The issue with the calculation is it doesn't cater for two-phase refrigerant release and there is currently a working group looking at the validity of the calculation and the possibility of adding two-phase releases as standard.

In simple terms however, and using the current less than perfect calculation, it has been shown on small equipment enclosures with air cooled condensers that if the condenser fan is left running continuously a release of HC refrigerant into the enclosure never allows the air/HC mixture to approach or exceed 50% LFL. These calculations have been confirmed using actual equipment and measuring the percentage of LFL reached with flammable gas detectors.

The calculation for the rate of release is also an issue. The calculation uses the leak hole size, but the RAC industry does not currently have data regarding leakage in terms of a cross sectional area. There will be a range of sizes and this could vary with types of HC system and components employed, but the hole size is a critical parameter in determining the resultant Vz. If we use a large hole we are going to over classify the zone around a piece of equipment, conversely if we under size the hole our flammable zone could be greater than expected in a real leak scenario.

Work is ongoing to ascertain a range of 'standard hole sizes' for calculation purposes and a future project with the HSE is currently being discussed to scientifically test the calculation in EN60079-10-1 to prove its validity and modify it accordingly for HC's and ammonia.

ATEX 137 (99/92/EC) and DSEAR[3]

Once the equipment has been manufactured to the correct harmonised standards consideration has to be given to the location of the equipment and sources of ignition that might be present in that environment. Dimensions of the potentially flammable zone should be provided by the equipment OEMs so designers / project managers can assess the impact on other equipment and devices installed in the location. For example, a piece of equipment might need to be compliant with EN60079 to be located adjacent to an HC system.

EN60335[5]

Some of the systems used by Waitrose are appliances which are covered by EN60335. This standard includes some guidance on the use of hydrocarbon refrigerants but as this standard is not harmonised with ATEX guidance in EN60079 has been used instead. EN60335-89 clearly directs the manufacturer to other standards if the system employs a charge >150g of HC.

Training

EN378 specifies that engineers working with hydrocarbon refrigerant should be competent to handle flammable refrigerants. All engineers working on Waitrose sites have attended the BOC[6] hydrocarbon refrigerant training course which includes:

- Basics of hydrocarbon refrigerants;
- Safety aspects, including flammability and sources of ignition;
- A practical overview of ATEX 95 & 137;
- The safe working environment;
- Service procedures for hydrocarbon refrigerant systems, including leak testing, un brazing and brazing, charging, disposal, component replacement;
- Maximum charge sizes.

Engineers' knowledge is assessed at the end of the session.

Servicing hydrocarbon refrigerant systems on a shop floor

A procedure for safely removing hydrocarbon refrigerant from a system prior to unbrazing joints was developed for engineers working on a shop floor (or any other area where venting to outside is not possible because of the location or the charge size).

The procedure is to recover the refrigerant (using an appropriate recovery machine) until the system is under partial vacuum. The system is then filled to a pressure of 0.5 bar g with oxygen free nitrogen and vented to atmospheric pressure before unbrazing joints. This ensures as much hydrocarbon refrigerant as possible has been removed from the system. This procedure is now included in all hydrocarbon refrigerant training and was 'live' tested to verify its effectiveness.

Partner awareness

Short training sessions have also been provided to John Lewis Partners (store manager etc) so they are aware of the benefits and differences in the new refrigeration systems, in particular with regard to hydrocarbon refrigerants. From a day to day perspective, the major difference is ensuring all engineers servicing the systems have the appropriate training (demonstrated by a photo ID card), validated by maintenance management system on signing in.

Development of the water cooled cabinets

A range of display cabinets with hydrocarbon refrigerant water cooled condensers was developed by Carter Retail Equipment (CRE) specifically for the Waitrose stores. This required the development of a new integral system to an outline specification, for example covering size, from Waitrose.

Physical Size Constraints

The requirement was to produce an integral case without losing the look and feel of a remote cabinet – in essence:

- no large compressors underneath or on top of the case;
- no significant increase in noise;
- good refrigerant containment and reliability; use of a natural refrigerant.

Another part of the brief was to incorporate a controlled amount of heat of rejection that could be channelled into the store environment to offset the net environmental cooling effect of the open fronted cabinet.

Compressor Selection

The refrigeration load was already known for the cases (in remote format) so the next step was to look at compressor availability and selection. Because of the constraints detailed above reciprocating and vertical scroll compressors were ruled out. CRE already had experience of the Hitachi range of ZS scrolls in the past as they had been used for a similar project on Heathrow T5 in 2007 – albeit on R404A.

The compressors were initially selected using R404A data (as this was the only data available). The compressors would be operating outside their usual range because of the lower condensing temperatures (resulting from the use of water as the cooling medium) so the data for capacity and power consumption was extrapolated. This highlighted shortfalls in capacity on some of the larger applications (3.75m roll in milk cases and 3.75m half glass door frozen food) which initially limited the range of cases available to the client.

Compressor capacity (duty) for condensing temperatures from 40°C to 30°C were taken from the Hitachi software selection programme. Hitachi (via Hawco Refrigeration) estimated a nominal 6% increase in compressor capacity per 5 K drop in condensing temperature could be expected – values for 25°C & 20°C were extrapolated (the shaded rows in the table above).

In addition, the R404A capacity was increased by 12% in line with a conservative estimate of the increase in capacity from R404A to R1270. This is based on information in the Bitzer Refrigerant Update[7].

Heat Rejection to Air

The cabinets reject a specified proportion of heat to the store space to offset some of the cooling effect of the cabinet. The target value was 750W per condensing unit which, on a typical Waitrose core store, would provide a total of 80kW of heat.

CONDENSING UNIT SCROLL COMPRESSOR SELECTION

Cabinet	Length (L)	Evap Temp [degC]	Duty (24hr) ISO3 [kW]	Duty per Comp Duty (18hr) Duty ISO3 (50%) [kW]			
HT	2.50	-7	3.79			2.53	
HT	3.75	-7	5.68				3.79
LT							
LT	2.50	-36	1.75	1.17			
LT	3.75	-36	2.63		1.76		

Case Duty per Compressor

Compressor	Condensing Temp [degC]	Duty [kW] @ -36degC	Duty [kW] @ -7degC	2.50 1.17	3.75 1.76	2.50 2.53	3.75 3.79
DS1836S1	20	1.823	5.966		84%		
0561375	25	1.699	5.566		90%		
2.5 HP	30	1.573	5.164		97%		
	35	1.447	4.762		105%		
	40	1.321	4.361		115%		
DS1529S1	20	1.430	4.504	71%			
0561374	25	1.345	4.283	75%			
2.0 HP	30	1.258	4.036	81%			
	35	1.172	3.790	87%			
	40	1.084	3.519	94%			
ZS1120S1	20	1.097	3.637				91%
0561370	25	1.045	3.420				96%
1.5 HP	30	0.990	3.197				103%
	35	0.933	2.973				111%
	40	0.870	2.744				120%
ZS7516S1 (138)	20	0.822	2.778			91%	
0561368	25	0.776	2.596			97%	
1.0 HP	30	0.726	2.414			105%	
	35	0.678	2.231			113%	
	40	0.627	2.047			123%	

Extrapolated Capacities high-lighted in blue (due to lower con-densing temperatures)

% figures are compressor loadings (R1270)

Compressor Selection Spreadsheet, showing extrapolation for lower condensing tempera-tures, and compressor loadings

The air volume was selected to achieve the required heat rejection to air and maintain minimum air flow for the HC system charge. The latter is to provide dispersion of refrigerant in the event of a leak and is specified in the Institute of Refrigeration Code for Flammable Refrigerants[8]

$$V_{air} = \frac{0.004 \times MR}{LFL} \qquad \frac{0.004 \times 0.88}{0.043} \qquad V_{air} = 0.082\ m^3/s$$

where ; V air = Air volume
0.004 = constant
MR = maximum charge
LFL = lower flamibility limit

The primary condenser was matched to the air volume with wide fin spacing (2 fins per inch) to avoid fouling. It is used in conjunction with a washable filter to reduce maintenance and improve reliability.

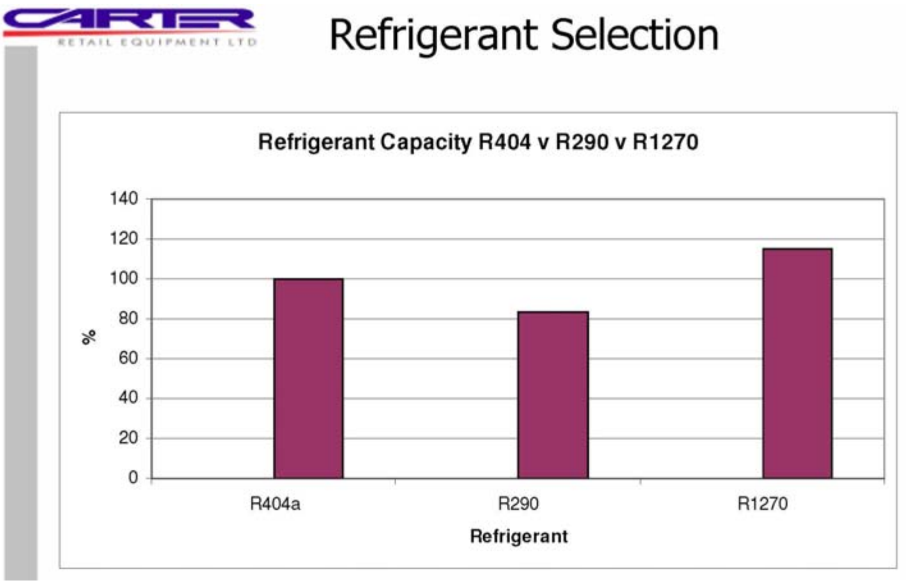
All design criteria for the plate heat exchanger was based on 100% total heat rejection to water to enable the proportion of heat rejected to air to be flexible.

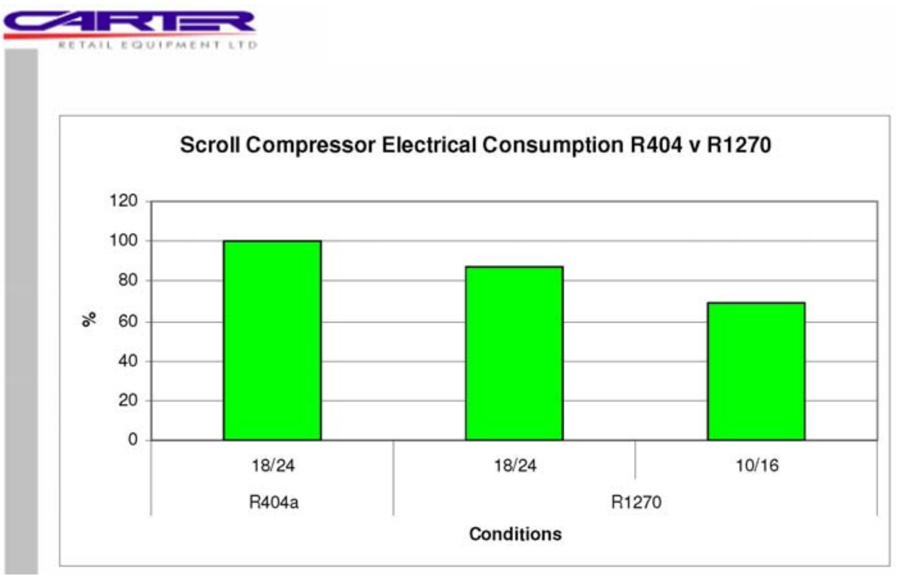
Hydrocarbon refrigerant Selection

R1270 (propene) was selected for the following reasons:

- Increased refrigerant capacity and efficiency compared R290 (see reference 7);
- CRE had carried out in house testing on R1270 and had recorded increases in capacity and reduced electrical loads (quantified below) which gave further system benefits.

The tables below show the results of testing at CRE for cabinets operating in Climate Class 3 as





defined in EN23953-2:2005[9].

18/24 is for a supply water temperature of 18^{O}C and a return of 24^{O}C.

10/16 is for a supply water temperature of 10^{O}C and a return of 16^{O}C (conditions which are used at certain times of year to improve electrical consumption or case capacity as required).

Electrical Component selection

Testing was carried out to determine the extent of the flammable zone in the event of a leak of hydrocarbon refrigerant as described in the section on the application of hydrocarbon refrigerants.

Production Activities and Constraints Charging HC refrigerants

The use of HC refrigerants in a production environment is covered by DSEAR[3] and as such various considerations were taken into account prior to the case build programme.

We took two views on the refrigerant handling testing process

1. **short term - two trial stores**
2. **long term - roll out of the project**

1) Short term – we were initially nominated for two trial stores. Due to cost implications on capital equipment the cabinets were constructed using a controlled manual process comprising the following:

SSOW (safe system of work) - in conjunction with the Carter Retail Health and Safety team a controlled process was drawn up with training, fire, evacuation procedures etc;

A dedicated 3 metre exclusion zone – as identified in DSEAR - this enabled the charging process to take place safely in a production environment;

Team of qualified/trained operatives - to control the quality of the process and the system integrity a team of two operatives were set up to carry out all key functions within the process. They were supported by operatives as and when required;

The use of existing Helium leak detection equipment - an A'Gramkow HRS6 automatic helium leak detection machine is currently used for all coil assembly production and has the benefit of the following

a. evacuation level to 10mbar
b. leak check to from 10mbar
c. Helium pressure test to 5bar
d. Helium leak check to 4.9 bar g
e. Helium sniffer check – capability to trace leaks down to 3g pa equivalent
f. OFN (oxygen free nitrogen) holding charge to 3.5 bar g;

A controlled manual charging process - each system was evacuated, leak checked (vacuum check) then manually charged in accordance with agreed charge weights (determined by lab testing of each case type);

100% manual testing regime - every case, upon charging, was coupled to a chilled water circuit and run tested for 30mins, checking primarily for frosting on all capillary circuits plus manual leak checking. The case was then electrically safety tested prior to dispatch.

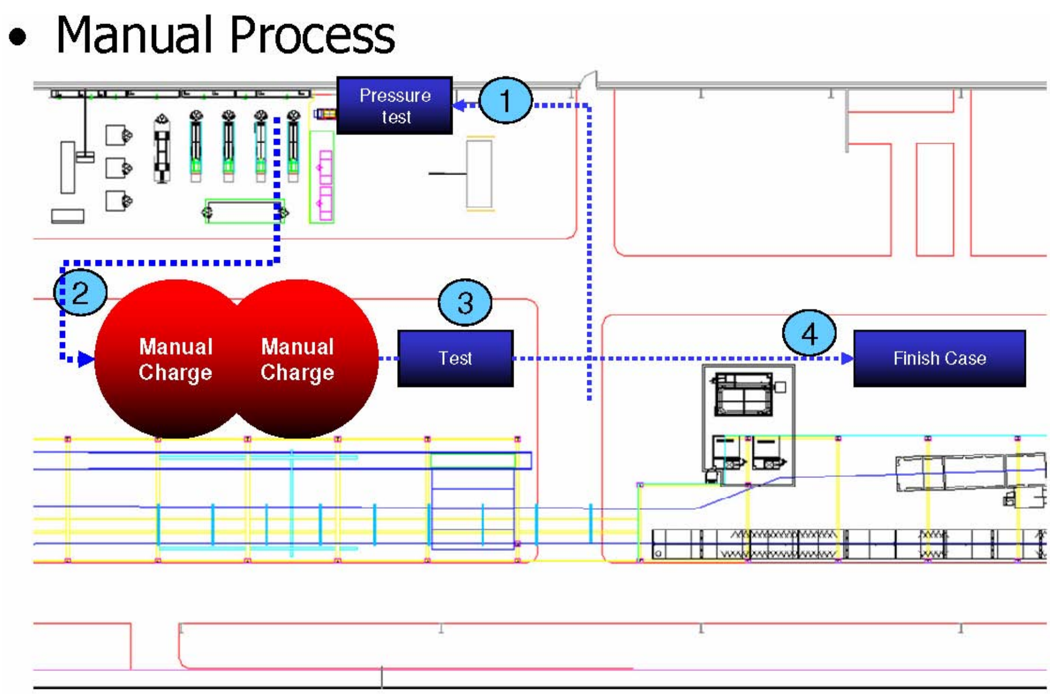
Whilst ensuring product quality , this system is very time consuming and had a major impact on production capabilities.

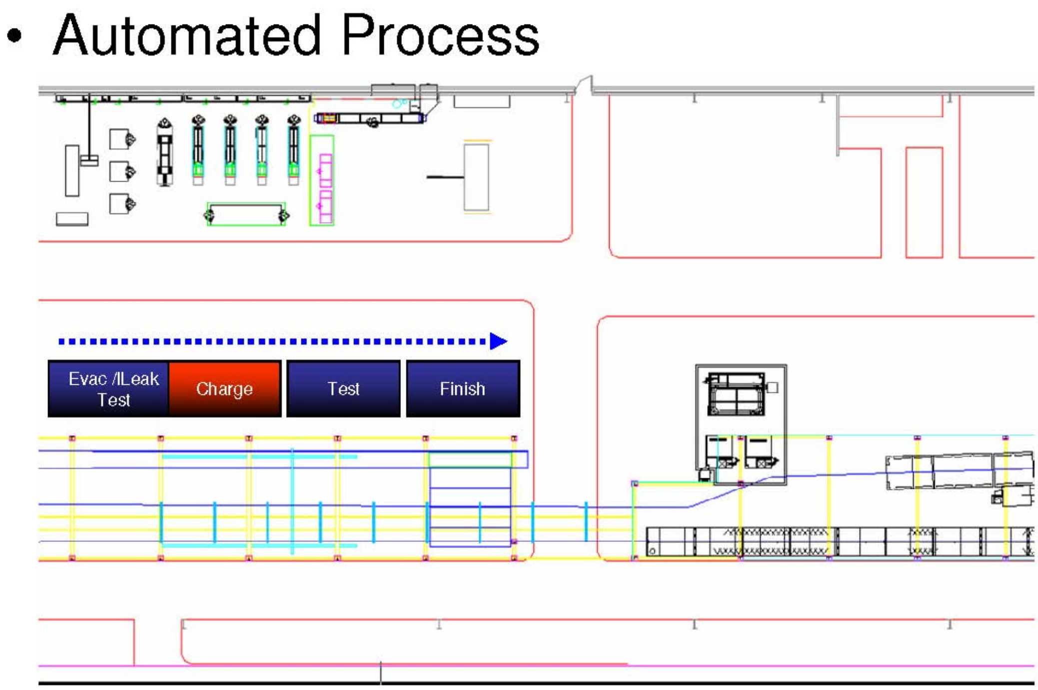
2) Long Term – Once the client had committed to this system going forward CRE was in a position to install an automated system which had the following advantages over the manual system:

Minimum exclusion zone – An A'Gramkow Saramax HC charging station with a forced ventilated bunded area was installed, fully ATEX compliant;

Automated charging process -The Saramax downloads case specific charge parameters from a central data base, carries out an evacuation leak check to 0.25mbar and then charges to within 1 g of required charge weight. The system is then hermetically sealed;

Automated testing - An A'Gramkow CPT (central test station) is then used to carry out within limits testing. The case is connected to a chilled water supply and a clamp probe fitted to the compressor and thermocouples measure the ΔT across the compressor. The test period is 10 minutes





and all values must be within predetermined parameters to gain a pass. All values are stored for reference.

The diagrams above show the lay out for both the short and long term solutions.

Energy efficiencies gained through the use R1270

As part of the design process CRE benchmarked R404A data against R1270. This not only provided information on the benefits of the refrigerant but also gave more data to extrapolate applications outside of existing Hitachi data.

On back to back testing there was a consistent 16% energy saving when using R1270 over R404A in the same application , this applied to both high temperature and low temperature application.

R404a v R1270 Comparison Data					
			R404a	R1270	% Saving
Case Type	Model	Length	DEC (watts)	DEC (watts)	
FHC	IC	2.50m	1424	1196	-16%
HGD	GD	2.50m	1514	1272	-16%

DEC = direct electrical consumption (watts)
Tests carried out in ISO 3 test conditions

Future plans

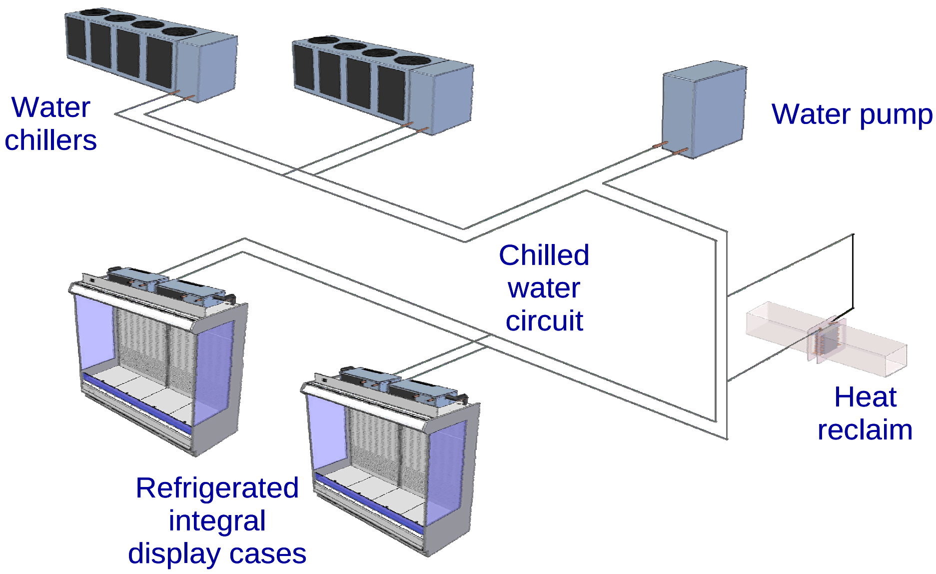
Further development is planned to improve further the performance of this conecpt:

- Optimisation of system design to continually improve energy reduction and reliability.
- Continued improvement of cabinet design and efficiency.
- Further integration of refrigeration design within wider carbon reducing initiatives.

The authors would like to thank John Lewis Partnership, Carter Retail Equipment and Cool Concerns Ltd for the time and resource required to produce this paper.

References:

[1]2010 Guidelines to DEFRA / DECC GHG Conversion Factors for Company Reporting, version 1.2.1 FINAL, updated 06/10/2010.
[2]EN378-1:2008 Refrigerating systems and heat pumps - Safety and environmental requirements, part 1 Basic requirements, definitions, classification and selection criteria.
[3]ATEX - ATEX 95 (94/9/EC) and through ATEX 137 (99/92/EC). DSEAR (Dangerous Substances and Explosive Atmosphere Regulations) states the legal requirements for managing the risk of fire, explosion or similar events arising from dangerous substances at the workplace, so it covers ATEX 137.
[4]EN60079 - Explosive atmospheres.
[5]EN60335 Household and similar appliances - safety. EN60335-2-24:2010 – Particular requirements for refrigerating appliances, ice-cream appliances & ice-makers; EN60335-2-89:2010 – Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor.
[6]BOC Hydrocarbon Refrigerant Training session, run by Cool Concerns Ltd.
[7]Bitzer Refrigerant Update 16.
[8]IOR safety code of practice for refrigerating systems utilising A2 & A3 refrigerants – section 4.9.
[9]EN23953-2:2005 Refrigerated display cabinets. Classification, requirements and test conditions.



Simple schematic of water cooled system.