Retail refrigeration: Central systems

Significant energy savings can be achieved by simple measures such as paying attention to the commissioning and control commercial refrigeration systems. Examining the energy efficiency opportunities while approaching CFC/HCFC phase-out could transform essential change into profitable action.

This guidance note has two primary purposes:

- The identification of energy saving opportunities which can be implemented while addressing CFC/HCFC phase-out.
- To assist in the creation of a company strategy for managing CFC/HCFC phase-out.

Background

Scientific observation has shown that the concentration of ozone in the stratosphere is decreasing. This thinning of the ozone layer is thought to be caused by the release of volatile chemicals containing chlorine and bromine, particularly those which don't break down in the lower atmosphere. To prevent further damage, the Montreal Protocol was signed by all the major nations of the world. As a result, the production of CFCs and HCFCs, the fluids used in refrigerating machinery, is being phased out (see Table 1 and Table 2) and very shortly the only source of CFCs will be reclaimed refrigerant. Recent history shows that current time-scales are likely to be superseded by more stringent phase-out dates. HCFC phase-out will almost certainly occur before the dates shown in Table 2.

A range of distributed retail display cabinets which are fed by central refrigeration systems are available to operate in the temperature range of -30°C to +5°C and typically adopt R12 or R502 as the refrigerant, with R22 also being a common choice. Both R12 and R502 are classed as CFCs and availability will be restricted in the near future (Table 1). It is therefore imperative that managers address the issue of phase-out now and create a coherent strategy for dealing with new and existing plant. HCFCs (e.g. R22) are also controlled by the Montreal Protocol and although their phase-out time scale is not as pressing, a contingency plan should be created as insurance against the acceleration of current schedules.

Table 1: CFC phase-out dates

	Production relative to 1986 consumption	
	EC	**Protocol**
1.1.1994	85% cut	75% cut
1.1.1995	100% cut	
1.1.1996		100% cut

Table 2: HCFC phase-out dates

1996:	Freeze at 1989 HCFC consumption + A x [1989 CFC consumption] (ODP weighted)	
	EC (A=2.6%)	**Protocol (A=3.1%)**
2004	35% cut	35% cut
2007	60% cut	
2010	80% cut	65% cut
2013	95% cut	
2015	100% cut	90% cut
2020		100% cut

Energy saving opportunities

The need to address CFC/HCFC phase-out presents an ideal opportunity to implement energy efficiency measures. A high proportion of the energy wastage from refrigerating equipment arises from incorrect operation and poor commissioning of controls. Significant savings can often be achieved for little to no cost.

The main stages in assessing potential energy saving opportunities are (Figure 1):

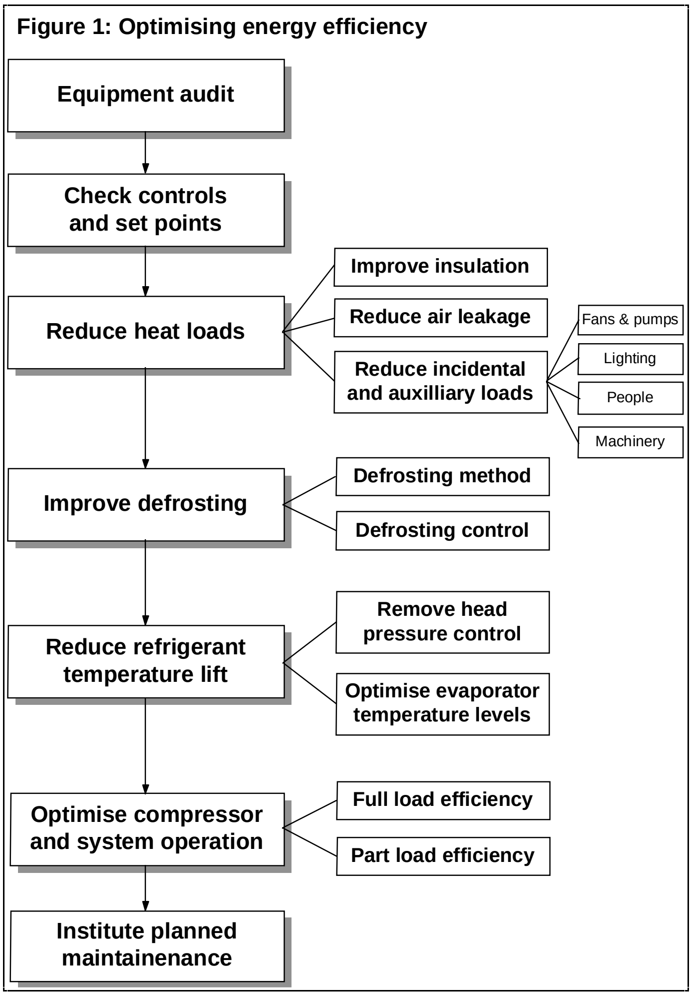
- Audit existing equipment
- Check controls and set points
- Reduce heat loads
- Improve defrosting
- Reduce temperature lifts in refrigerating plant
- Optimise compressor and system operation
- Institute planned maintenance

Audit existing equipment

The equipment audit is dealt with in detail in a later section (Managing CFC/HCFC phase-out). In brief, it involves identifying all refrigerating equipment owned by a company and creating a central index or database of relevant information. This will assist in deciding the suitability of particular equipment for energy saving measures.

Check controls and set points

Ensuring that controls are correctly commissioned is a relatively cheap and easy activity which can lead to large energy savings. Very narrow temperature control bands can result in equipment operating more frequently than necessary and leads to cycling which can reduce efficiency. Adjusting the time constants of the control algorithm can easily remedy this. All thermostat set points should be checked. Overcooling by 1°C can lead to an increase in energy consumption of between 1.5%-5%.



Reduce heat loads

Any reduction in heat loads results in a reduction in required refrigeration capacity and therefore energy consumption. There are three main methods for reducing heat loads:

- Improving insulation.
- Reducing air leakage.
- Reducing incidental and auxiliary gains.

- Insulation improvements

Heat loss through insulation is not as significant as the heat loss through air infiltration in open cabinets or where cabinets have doors which are regularly opened. The walls of the refrigerated cabinet should be regularly inspected to ensure there is no degradation of insulating materials. Thermographic inspection will show up cold areas where insulation is poor.

- Air leakage

The primary source of air ingress is through the open top of unsealed cabinets, while it will be through the door of cabinets which are normally sealed.

Much of the air ingress is unavoidable with these cabinets and is often a function of the unit design. Of course blinds, strip curtains or doors may be fitted to open cabinets but in many cases this will be unacceptable to the retailer. Blinds can be used at night and removed during the day.

Care should always be taken to ensure that the layout of goods within the cabinets is correct as they will have an effect on the airflow within the cabinet. Improper loading may cause greater air ingress in addition to preventing even refrigeration.

- Incidental and auxiliary heat gains

Air circulation fans, store and cabinet lights, and rejected heat from the condenser can all increase the load on the refrigeration system. The power for these items is thus paid for twice - first the direct power cost and then the refrigeration cost of removing the heat from the cabinet. The selection of efficient auxiliary equipment and the avoidance of its unnecessary use is therefore doubly important. Also, the cabinets should not be used as comfort coolers for the shopping aisles.

Improve defrosting

Defrosting is required to remove the frost which forms on an evaporator when the refrigerant boils within it at below 0^{o}C. Proper control of defrosting is essential for an energy efficient system. The defrost cycle should only be initiated when a layer of frost has developed and should stop immediately the frost has been removed. A time clock method may be satisfactory if the rate of frost formation is fairly constant. Other methods include directly detecting frost formation or by noting the fall in air velocity. Defrost completion should be detected by measuring the coil fin temperature or the refrigerant pressure in the evaporator. Reducing the humidity in the store by air conditioning will reduce both the refrigeration and defrosting load.

Reduce temperature lifts

The efficiency of refrigerating plant is dependent upon the size of the temperature lift between the evaporator and the condenser: the smaller the lift the more efficient the system.

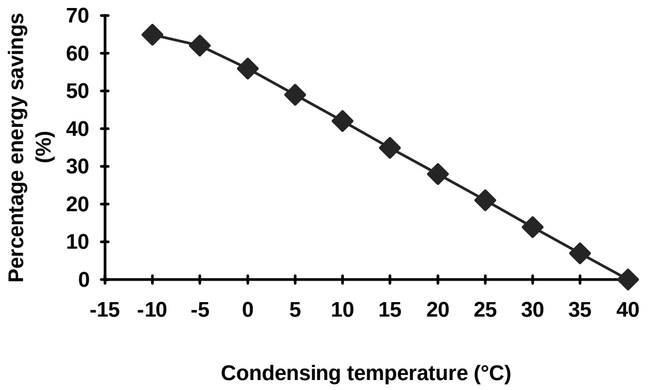
- Head pressure control

Many systems maintain a higher lift than is necessary through the use of head pressure control. This practice aims to maintain a high pressure in the condenser to ensure a controlled supply of refrigerant to the evaporator.

The control pressure can be reduced using a balanced port thermostatic expansion valve or an electronic expansion valve, while the installation of a liquid line pump can further reduce the need for such control. Lowering the control pressure allows the condensing pressure to fall as the outside temperature falls from the design condition and can improve energy efficiency by 50%, particularly during winter. The cost of these measures varies between 150 - £1,500 if installed at the time of refrigerant replacement and will normally pay back in about two years.

Figure 2 illustrates the energy savings which can be achieved following re-adjustment of a system initially set to maintain head pressure at a design day condensing temperature of 40°C (assuming an evaporating temperature of -30°C).

Figure 2: Energy savings from adjustment of head pressure control (schematic)



- Optimising evaporator temperature levels

Where more than one refrigerated cabinet is being cooled by the same compressor set then energy will be wasted if they are not operating at the same evaporating temperatures. If the cabinet temperatures differ by more than 10°C then the use of separate compressor sets should be considered for each of the different temperature levels (this will of course depend on the number of cabinets being fed by the system).

Optimise compressor & system operation

Where compressor capacity control is required then normally the most efficient method is to run compressors in parallel and to switch units on or off to achieve the desired refrigerating duty. Modern variable speed drives are also a fairly efficient option. Capacity control methods will be optimised by the use of electronic expansion valves which have better turn down than standard thermostatic valves.

The practice of reducing capacity by running all compressors at part load simultaneously, throttling the suction gas or passing vapour from the high pressure side directly to the compressor are all very inefficient and can increase energy consumption by up to 50%.

Institute planned maintenance

Systematic, regular maintenance is the best way to ensure that plant continues to run efficiently and reliably. It is desirable that a company wide maintenance programme is instituted following the equipment audit.

Managing CFC/HCFC phase-out

The deadline for manufacturers to cease CFC production is imminent. Organisations should begin appraising their refrigeration equipment and identify the options for change, before legislation forces their hand. Rushing decisions could lead to costs which might otherwise be avoided. A suggested strategy is given below and is shown schematically in Figure 3.

Appoint a responsible person

Someone within the organisation, preferably a manager, should be given the responsibility of co-ordinating and implementing an organisation-wide refrigerant strategy. This is essential if, for example, CFCs contained in existing equipment are to be managed effectively.

Audit equipment

Initially, identify all refrigeration systems and set up a central index or database. The following details should be entered for each system:

- System use
- System type (e.g. reciprocating, screw)
- Design capacity
- Manufacturer/supplier
- Model and serial number
- Peak load
- Current refrigerant
- Refrigerant charge
- Age and cost when new
- History (leaks, maintenance etc.)

Appraise equipment

Each system should be appraised for:

- Remaining economic lifetime:
  replacement may be the best option, even when retrofit is possible, for plant nearing the end of its useful economic life.

- Current over capacity:
  switching to some new refrigerants may result in a reduction in system capacity. Typically, refrigeration plant is oversized; it is important to know the degree of over capacity.

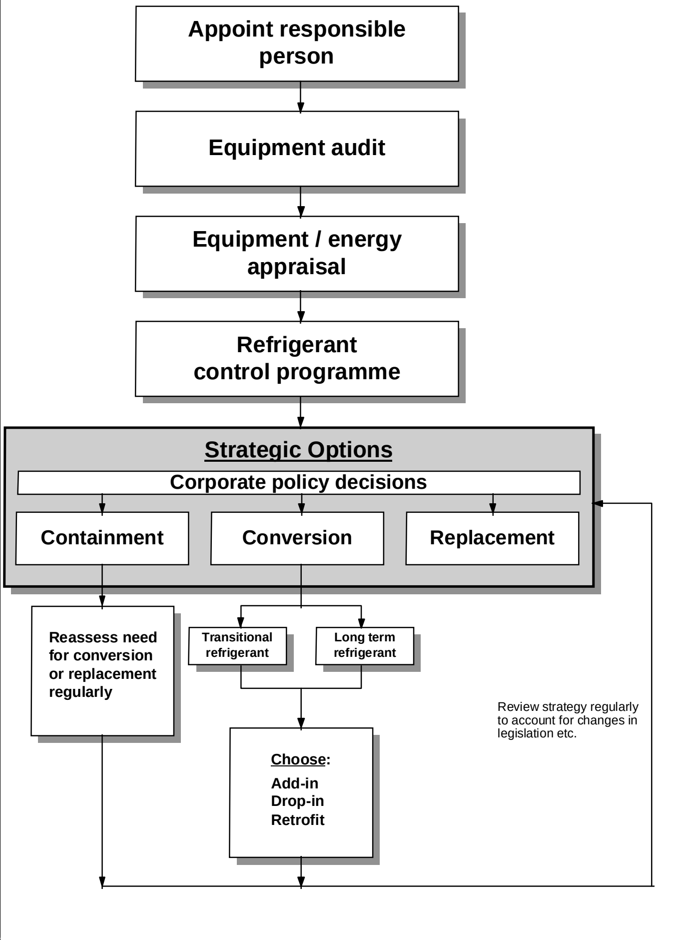
- Energy efficiency:
  opportunities for improving equipment efficiency should be identified. Equipment with a high potential for energy saving should be prioritised within the phase out strategy, while equipment with low efficiency should be considered for total replacement. Where an organisation has CO_2 emissions targets it may impose minimum plant efficiencies. In some cases, switching to a new refrigerant may result in reduced plant efficiencies, enhancing the economics of total replacement.

- Cost of conversion.

- Cost of replacement.

These options may be limited by the corporate policy decisions discussed below.

Figure 3: CFC and HCFC phase-out strategy



Implement refrigerant control programme

Having a central refrigerant database and a responsible manager allows the existing refrigerant 'bank' to be effectively managed. Refrigerant from decommissioned plant can be recycled for use in other equipment. A corporate policy should be developed to ensure regular maintenance, leak checking and adherence to good refrigeration practice.

Strategic options

An organisation must make a number of strategic decisions regarding its approach to existing equipment. These are outlined below:

- Corporate policy decisions

An organisation must decide at an early stage on its internal and public stance with regard to certain political issues and equipment performance criteria. For example, should they:

- choose global warming potential (GWP) or total equivalent warming impact (TEWI) as the basis for calculating contribution to global warming?

- use transitional refrigerants in the knowledge that they are not seen as environmentally friendly and will be phased out in the near future?

- set minimum acceptable standards for energy efficiency?

The options available for dealing with existing equipment, guided by the corporate policy decisions, are principally:

- Containment
- Conversion
- Replacement

- *Containment*

Containment, or ensuring that refrigerant remains within the equipment, often involves not interfering with sound plant and should always be the first strategic choice where possible; it will almost certainly be the cheapest, especially for small hermetic systems. However, containment is not an excuse for inaction. Leak detection should be installed where it is appropriate and contingency plans should be developed to ensure there is an adequate supply of refrigerant for servicing and to allow future conversion or replacement should this become necessary.

- *Conversion*

A history of refrigerant leakage would make a policy of containment unsuitable. Given that economics (e.g. remaining lifetime, conversion cost) do not favour replacement, then conversion will be the strategic choice for the majority of refrigerating equipment. There are a large number of alternative refrigerants available to replace existing CFCs and HCFCs and it is the shear choice which is daunting.

As previously mentioned, R12 and R502 are predominantly used in refrigerated cabinets. Both of these refrigerants are CFCs and face phase-out as a result of the Montreal Protocol. This section describes how to approach the conversion of R12 plant and illustrates how the choice of alternative refrigerants can be simplified. The same arguments can equally be applied to R502 equipment. Figure 4a lists the performance data of some potential R12 alternatives at evaporating temperatures of -15°C and +5°C. These tables are ***not*** exhaustive, but do list most of the alternatives currently manufactured by the major refrigerant producers[1].

The table gives the actual performance details of R12 its alternatives, while their COPs and SCDs (both shaded) are shown ***relative*** to R12. Figure 4b shows similar data for R502 and its alternatives.

The process for choosing an alternative can be simplified by following the decision tree shown in Figure 3. The tree follows simple logic :-

1. The new refrigerant should, if possible, have long term availability. This is insurance against phase-out time scales being moved forward for transitional refrigerants.
2. Where drop-in refrigerants are available they should be used - this will minimise cost and disruption.
3. Where a long term drop-in is not available a transitional drop-in should be used in place of a long term retrofitable refrigerant. This will delay the need for costly system modifications while a long term drop-in becomes available.

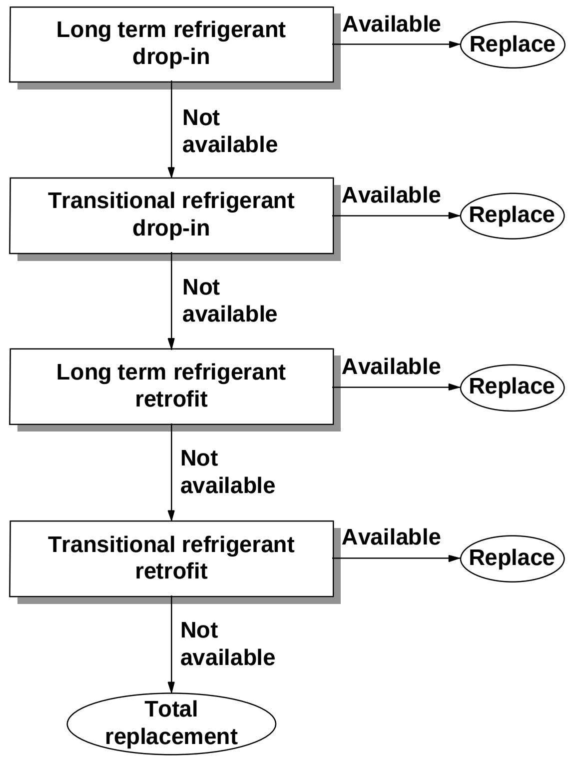
   This gives the following priority:

   - Long term drop-in
   - Transitional drop-in
   - Long term retrofit
   - Transitional retrofit

   Where no alternative refrigerant is available total equipment replacement will be necessary.

[1]These tables are based upon information available at the time of compilation of this information sheet. It is acknowledged that new refrigerants will become available in the future.

Figure 4: Choosing an alternative refrigerant



Applying the logic of Figure 4 to the table of R12 alternatives in Figure 5a gives the following results (similar logic can be applied to the table of R502 alternatives in Figure 5b):

Long term drop-in replacements:

There are no refrigerants in this category.

Transitional drop-in replacements:

- FX56
- FX57
- G2015
- MP39
- MP66

The list above shows a selection of transitional drop-in replacements available. However, apart from G2015 and MP39, the rest are intended for low temperature use (manufacturers' information). Strictly, G2015 is an add-in and so is easier to install than a drop-in. MP39 is not a true drop-in and requires a single oil change to a POE or alkyl benzene oil. It will also give discharge temperatures which exceed those of R12 by about 10°C.

Long term retrofit replacements:

- R134a

Where none of the above are suitable, R134a should be the next choice. It is the only refrigerant in this category and is the manufacturers' favoured choice in many applications (although not necessarily the best option) being suitable for most R12 applications. Use of R134a will generally require system modifications and oil flushing.

Transitional retrofit replacements:

There are no refrigerants in this category.

- *Replacement*

Total equipment replacement should be seen as the final option - but will be necessary when containment and conversion are not feasible. The complexity and cost of conversion can vary dramatically between different plant types and often depends largely on whether a drop-in refrigerant is available. Conversion of centrifugal plant in particular can be very expensive and even when conversion is possible economics may favour replacement (e.g. when equipment is nearing the end of its useful life).

Although replacement represents an expensive choice, it does allow the use of new refrigerating plant designed specifically for use with alternative refrigerants and optimised for energy efficiency. For example, some new refrigerants are intended for use exclusively in new equipment and heat exchanger performance can be optimised for use with non-azeotropic refrigerant mixtures by taking advantage of temperature glides to achieve greater energy efficiency.

Education

The handling of many new refrigerants and oils differs significantly from traditional techniques. It is imperative that staff are trained to work with the new materials. Reduced efficiencies and plant failures can arise from incorrect procedure being followed, particularly where refrigerant replacement is being carried out. Advice regarding training and registration can be obtained from the HRAI in Canada (Tel: 010 1 (905) 602 4700) and the HEVAC Association in the UK (Tel: 44 (6285) 31186).

Figure 5a: Performance of R12 alternatives*

Refrigerant	**R12**		**R134a**		**MP39**		**MP66**		**FX56**		**FX57**		**G2015**	
ASHRAE No.	R12		R134a		R401A		R401B						R405	
Manufacturer	many		many		DP		DP		EA		EA		GT	
Status			Long term		Transitional		Transitional		Transitional		Transitional		Transitional	
Drop-in			No		Near**		Near**		Yes		Yes		Yes	
Retrofit			Yes		-		-		-		-		-	
Available			Yes		Yes		Yes		Yes		Yes		Yes	
	Tev (°C)		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**	
	-15	**+5**	**-15**	**+5**	**-15**	**+5**	**-15**	**+5**	**-15**	**+5**	**-15**	**+5**	**-15**	**+5**
SCD (dm^3/kJ)	0.82	0.40	1.05	0.97	0.87	0.85	0.82	0.80	0.89	0.86	0.84	0.82	0.85	0.81
COP	2.66	4.88	0.97	0.99	1.00	0.94	0.98	0.99	0.97	1.00	1.01	0.98	0.92	0.95
Pev (bar a)	1.82	3.62	1.64	3.49	1.98	4.06	2.10	4.23	1.90	3.99	2.04	4.22	2.24	4.62
Pco (bar a)	9.60	9.60	10.1	10.1	11.3	11.3	12.0	12.0	11.1	11.1	11.8	11.8	12.7	12.7
Tdis (°C)	71.4	59.6	67.5	57.2	85.2	71.2	106	70.3	89.7	71.0	87.5	71.5	70.1	59.9

Figure 5b: Performance of R502 alternatives*

Refrigerant	**R502**		**R22**		**R134a**		**HP80**		**HP81**		**69S**		**69L**		**FX10**		**Propane**		**Ammonia**	
ASHRAE No.	R502		R22		R134a		R402A		R402B		R403A		R403B				R290		R717	
Manufacturer	Many		Many		Many		DP		DP		RP		RP		EA				Many	
Status			Transitional		Long term		Transitional		Transitional		Transitional		Transitional		Transitional		Long term		Long term	
Drop-in			Yes		No		Near**		Near**		Yes		Yes		Yes		Yes		No	
Retrofit			-		Yes		-		-		-		-		-		-		No	
Available			Yes		Yes		Yes		Yes		Yes		Yes		Yes				Yes	
	Tev (°C)		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**	
	-25	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**
SCD (dm^3/kJ)	0.75	1.15	0.99	0.98	1.80	1.96	0.93	0.94	0.94	0.94	0.93	0.92	1.0	0.98	0.99	1.00	1.14	1.12	0.98	1.03
COP	1.88	1.47	1.08	1.10	1.06	1.07	1.01	1.01	1.04	1.05	1.04	1.05	0.99	0.98	1.00	1.03	1.05	1.07	1.08	1.10
Pev (bar a)	2.41	1.61	2.01	1.32	1.06	0.66	2.51	1.67	2.33	1.54	2.40	1.60	2.54	1.71	2.35	1.55	2.03	1.37	1.51	0.93
Pco (bar a)	16.8	16.8	15.3	15.3	10.2	10.1	18.2	18.2	17.1	17.1	16.9	16.9	17.4	17.4	17.2	17.2	13.7	13.7	15.6	15.6
Tdis (°C)	74.5	81.9	107	122	74.1	82.3	75.8	82.8	86.1	95.5	86.8	96.1	72.7	73.4	85.1	93.1	71.3	78.2	218	263

Refrigerant	**R502**		**Klea 60**		**Klea 61**		**Klea 66**		**HP62 FX70**	
ASHRAE No.	R502		R407A		R407B		R407C		R404A	
Manufacturer	Many		ICI		ICI		ICI		DP/EA	
Status			Long term		Long term		Long term		Long term	
Drop-in			No		No		No		No	
Retrofit			Yes		Yes		Yes		No***	
Available			Yes		Yes		Yes		Yes	
	Tev (°C)		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**	
	-25	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**	**-25**	**-35**
SCD (dm^3/kJ)	0.75	1.15	1.04	1.08	1.03	1.07	1.09	1.13	0.95	0.98
COP	1.88	1.47	1.02	1.02	0.96	0.95	1.04	1.04	0.97	0.96
Pev (bar a)	2.41	1.61	2.10	1.35	2.41	1.57	1.92	1.22	2.63	1.75
Pco (bar a)	16.8	16.8	17.5	17.5	18.9	18.9	16.5	16.5	18.7	18.7
Tdis (°C)	74.5	81.9	87.3	96.5	73.7	80.1	92.2	102	67.0	67.1

* Tco = 40°C
** A single oil change to a polyol ester or alkyl benzene type is recommended.
*** Although retrofits are possible they are not recommended by the manufacturer.

Key:
RP: Rhone-Poulenc, DP: Du Pont, EA: Elf Atochem,

Note:
The shaded area gives the performance of alternative refrigerants relative to R12 at the same evaporating temperature.
∴ To find the COP of Klea 60 at Tev= -25°C, COP= 1.02*1.88 = 1.91

Legend

SCD: specific compressor displacement
COP: coefficient of performance
Pev: evaporating pressure
Pco: condensing pressure
Tdis: discharge temperature

Case study - Refrigerant conversion

The conversion of supermarket distributed refrigerated display cabinets fed from a central system is outlined here. The system was converted from R502, a CFC, to R403b a transitional blend of refrigerants. As R403b contains HCFCs it can only be viewed as an interim solution. To its advantage, it is a drop-in refrigerant while most of the alternatives with long term availability are not.

The central refrigeration system comprised of four 15kW reciprocating compressors, each with 50% capacity control capability. These met the refrigeration demand of 22 frozen food display cases and five cold store evaporators. The performance of the system was compared with a similar sized system in the same store which was left to operate with R502.

The 480kg system charge was pumped down into the high pressure receiver leaving a system pressure of about 0.8bara. The R502 was then transferred to recovery cylinders using decanting equipment. The oil was then changed as a matter of routine and a fresh charge of the *same* lubricant was added. A charge of 420kg of R403b was then added in the liquid phase (charging in the vapour phase is not recommended). The display cabinet and cold store loads were re-introduced to the system one at a time while the compressors were controlled manually (via computer) to progressively balance the increasing load. No hardware changes were carried out.

Continuous monitoring showed an increase in refrigeration capacity and up to 6% higher energy efficiency than the R502 system used for comparison. The compressor discharge temperature was consistently lower than that of the R502 system. Oil samples showed no degradation and no component wear was observed. However, two gallons of surplus oil were removed from the system suggesting that R403b has better oil return characteristics than R502.

A word of caution. R403b has a sister refrigerant R403a which gives similar refrigerating performance but produces discharge temperatures of around 14°C higher than R502 while R403b produces similar discharge temperatures. Each R502 application should be carefully considered to ascertain which of these alternatives is more suitable.

Case study - Energy efficiency

A Danfoss Smart case controller and electronic expansion valves were installed at Tops Market 22 in Niagara Falls, New York. The installation covered one low temperature (two stage) rack and one medium temperature rack connected to forty three display case evaporators and five evaporators in a meat preparation room and walk-in meat boxes. R22 was used as the refrigerant in both racks. The head pressure was allowed to float in both systems.

The electronic expansion valves were fitted in parallel with the existing thermostatic expansion valve and operation was switched between the two systems three times per week to allow a fair comparison to be made. Energy savings were achieved with the electronic expansion valve because lower levels of superheat out of the evaporator allows better heat transfer and so higher evaporating pressures are used. This also reduces ice formation on the coils allowing lower ice build up and faster recovery from defrosting.

The energy savings achieved averaged 9% with increasing savings in warmer months.

A Liquid Pressure Amplifier was fitted to the high temperature rack of the Big Fresh Mt. Wellington store in New Zealand. The rack used four D4DA-1000 Copeland compressors and one 4DH-1500 giving a nominal capacity of 89.5 kW using R12 refrigerant.

After installing the LPA the evaporator temperature rose by 6.4 ºC, indicating that flash vapour in the suction line had adversely affected the performance of the expansion valves. The measured energy saving was 32%.

Abbreviations and definitions

CFC	(chlorofluorocarbon)	Refrigerants containing chlorine. Have high ODP and high GWP. Widely used as refrigerants
HCFC	(hydrochlorofluorocarbon)	Contain chlorine, but have lower ODP than CFCs. Wide range of GWPs.
HFC	(hydrofluorocarbon)	Contain no chlorine so do not attack ozone. Some have high GWPs
Add-in		A refrigerant which can be added to equipment without removing the existing refrigerant. No modifications required.
Drop-in		A refrigerant which can be used in equipment without the need for significant changes. The existing refrigerant must, however, be decanted.
Retrofit		A refrigerant which can be used in equipment but will require modifications to the plant. This can vary between an oil change to compressor replacement.
Retrofill		This term is used to describe the action of replacing an existing refrigerant with an alternative. It therefore strictly applies to drop-ins and retrofits, but can also be applied loosely to add-ins.
Azeotrope		A mixture of refrigerants which behave thermodynamically as though they were a single fluid. It boils at a constant temperature.
NARM	(non-azeotropic refrigerant mixture)	A mixture of refrigerants whose composition in the liquid stage varies from its composition in the vapour stage during condensation and evaporation. Importantly, phase change occurs over a temperature range referred to as the glide and not at a fixed boiling point.
NARB	(non-azeotropic refrigerant blend)	An alternative term meaning the same as NARM.
ODP	(ozone depletion potential)	The ability of a refrigerant to destroy stratospheric ozone relative to R11 which is defined to have ODP=1.
GWP	(global warming potential)	A measure of a refrigerants ability to contribute to global warming relative to carbon dioxide which is defined to have GWP=1.
HGWP	(halon global warming potential)	An alternative measure to the GWP, taking R11 as the datum rather than carbon dioxide. It results in significantly lower values for alternative refrigerants i.e. HFC134a: GWP=420, HGWP=0.28 (over 500 yrs).
TEWI	(total equivalent warming impact)	The TEWI is a measure of a system's contribution to global warming. It takes account of the refrigerant GWP and the carbon dioxide generated as a result of power consumption. The carbon dioxide emissions are often the most significant contributor to global warming.
AFEAS	(alternative fluorocarbon environmental acceptability study)	A study to determine the environmental impact of alternative refrigerants
AREP	(alternative refrigerant evaluation programme)	A study to determine the performance of alternative refrigerants
COP	(coefficient of performance)	A measure of efficiency. Equal to cooling duty of plant divided by power consumption.
SCD	(specific compressor displacement)	A measure of the volume of refrigerant which a compressor must displace to achieve a unit of cooling.