Cold Storage Refrigeration

Significant energy and financial savings can be achieved in cold storage refrigeration equipment by adopting simple measures. Examining the energy efficiency opportunities while approaching CFC/HCFC phase-out could transform essential change from an unavoidable expense into profitable action.

This guidance note has two primary purposes:

- To identify 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 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 Recent history shows that current phase-out dates are likely to be superseded by more stringent time scales. HCFC phase-out will almost certainly occur before the dates shown in Table 2.

Cold storage refrigeration systems typically use R502 (a CFC) and ammonia as refrigerants, although R22 (an HCFC) is also used in some applications. R502 availability will be severely restricted in the near future (Table 1). It is imperative that managers address the issue of phase-out now and create a coherent strategy for dealing with new and existing plant. HCFCs are also controlled by the Montreal Protocol and although their phase-out time scale is not as pressing (Table 2), a contingency plan should be created as insurance against the acceleration of current schedules. Ammonia use is unaffected by this legislation.

Table 1: CFC phase-out dates

	Production relative to 1986 consumption	
	EC	Canada
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%)	Canada (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 cold stores arises from incorrect operation of equipment and poor commissioning of controls, so significant savings can be achieved for little to no cost.

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

- Audit existing refrigerating 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

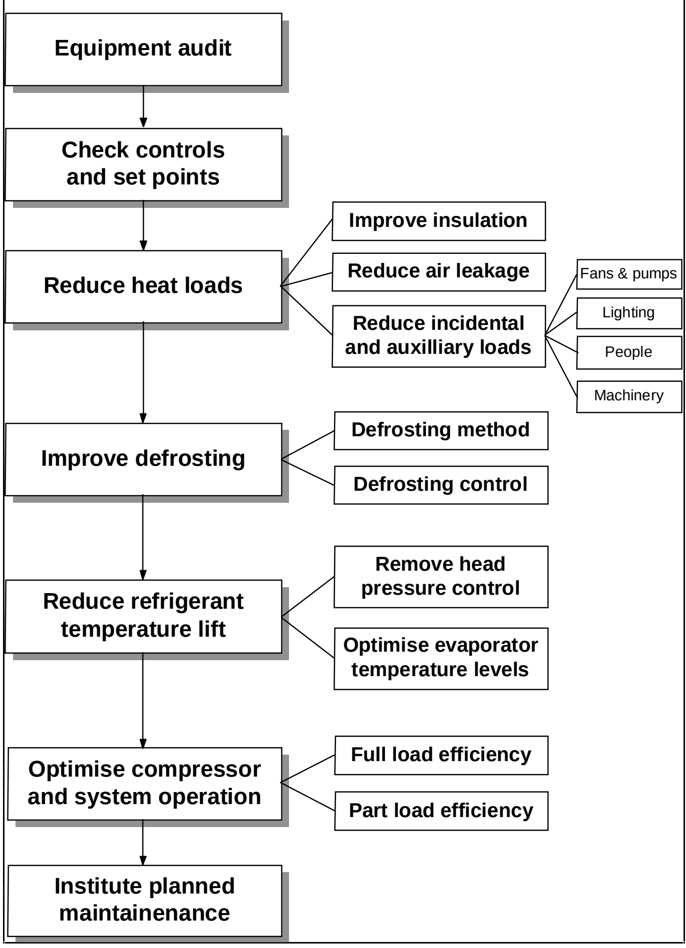
Audit existing equipment

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%-3%.

Figure 1: Optimising energy efficiency



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

The walls of a refrigerated space should be well maintained to guard against damage or degradation of the insulating material. visual inspection will give first indications of problems while thermographic inspection will show up cold areas where insulation is poor.

- Air leakage

Air can leak through the degraded fabric of an enclosure or through an access such as a door. Taking the steps outlined above should prevent fabric leakage, while reducing air leakage through doors is outlined below:

Access is required to all cold stores for loading and unloading causing unavoidable air ingress. However, this ingress can be limited by a number of options, although the regularity of access will influence the decision. A tight fitting door must be used during periods where access is not required, but when access in necessary on a regular basis strip curtains or automatic doors can be used to limit the ingress. However, secondary sealing systems encourage users to neglect the use of the main door. An automatic door can reduce the cooling load by 150MWh per annum over strip curtains (2.4m x 2.1m doorway, 4.5 hours use per day, storage temperature of -25°C and external temperature of 15°C). The use of two entrances to a single store should be avoided where possible as it encourages air movement through the refrigerated space. If appropriate, airlocks should be considered.

- Incidental and auxiliary heat gains

Evaporator fans, air circulation fans, lights and machinery in the store 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 refrigerated space. The selection of efficient auxiliary equipment and the avoidance of its unnecessary use is therefore doubly important.

High efficiency fans should be installed where possible. As the peak loads occur in cold stores during and after loading, two-speed fans could result in significant savings. They can operate at a setback condition during periods of lower cooling demand (e.g. overnight).

High efficiency lighting such as high frequency fluorescents or sodium lights should be fitted when the lighting system requires refurbishment (check that they will re-strike at the cold store temperature). Care should be taken to ensure that the store is not over illuminated; levels of 150 to 300 lux are generally satisfactory. Non-uniform illumination may be acceptable, with higher levels being used near machinery and lower levels in passageways. A simple way of achieving this is to remove some of the lamps, but checks should be made to ensure that this will not adversely affect the controllers and the ballasts and that a safe and acceptable level of illumination will be maintained. In spaces which are intermittently occupied the largest potential saving is from switching lighting off when it is not required. A variety of control systems are available including time clocks, personnel detectors and delay-timers. Care must be taken to prevent an area being plunged into darkness while occupied and this may be achieved by having a permanent, but low level, of background illumination.

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 is satisfactory if the rate of frost formation is fairly constant, otherwise automatic methods of frost detection, directly detecting frost formation or noting the fall in air velocity should be used. Defrost completion should be detected by measuring the coil fin temperature or the refrigerant pressure in the evaporator.

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.

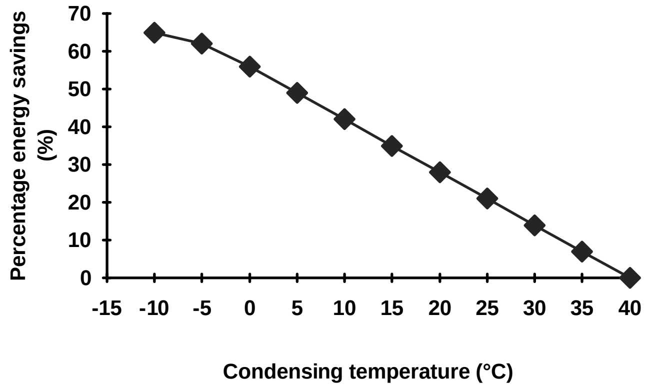
- Head pressure control

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 C$300 and C$3,000 (£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

When more than one refrigerated space 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 cold store temperatures differ by more than 10°C then the use of separate compressor sets should be considered for each of the different temperature levels.

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.)

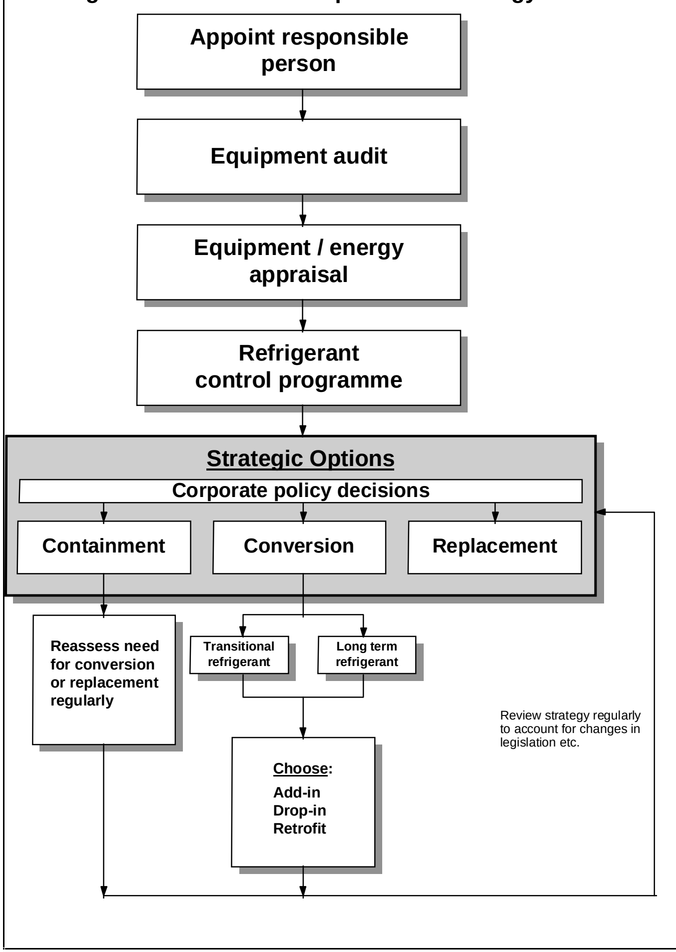
Appraise equipment

Each system should be appraised for:

- Need (is it essential?)
- 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.

Cold storage refrigeration is dominated by R502 equipment (and ammonia equipment which is not discussed here), with R22 equipment in use in some applications. Conversion from R502, the primary refrigerant, is considered in this guidance note. Figure 5 lists the performance data of many R502 alternatives at evaporating temperatures of -25°C and -35°C respectively[1]. These tables are ***not*** exhaustive, but do list most of the alternatives currently manufactured by the major refrigerant producers.

The tables give the actual performance details of R502 and its alternatives, while their COPs and SCDs (both shaded) are shown ***relative*** to R502. They show that there is little to separate any of the alternatives in terms of efficiencies and working pressures, however discharge temperatures of some alternatives can vary significantly from that of R502.

[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.

The process for choosing an alternative can be simplified by following the decision tree shown in Figure 4. The tree follows simple logic :-

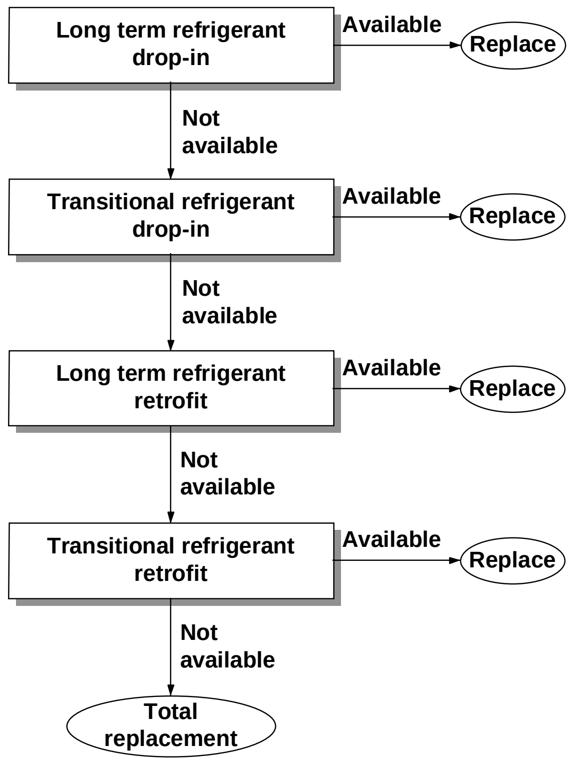
1. The new refrigerant should, if possible, have long term availability. This is insurance against phase-out time scales being moved forward for transitional refrigerants.
2. Where drop-in refrigerants are available they should be used - this will minimise cost and disruption.
3. Where a long term drop-in 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.

Figure 4: Choosing an alternative refrigerant



Applying the logic of Figure 4 to the table of R502 alternatives in Figure 5 gives the following results:

Long term drop-in replacements:

- None

There are no HFC refrigerants available in commercial quantities in this category, although alternatives may become available in the near future . It is therefore necessary to choose from another category, unless flammable refrigerants are acceptable in which case propane may be considered.

Transitional drop-in replacements:

- HP80
- HP81
- 69S
- 69L
- FX10

All of these refrigerants are suitable for use in cold store applications although some may be preferable to others in specific cases. HP81 gives higher discharge temperatures than R502 by about 12°C and is recommended for medium temperature applications while HP81 is recommended for low temperature applications. A similar argument applies to 69S and 69L, as the discharge temperature of 69S exceeds that of R502 by around 14°C. FX10 is recommended for use in all R502 applications.

Long term retrofit replacements:

- HP62/FX70
- Klea 60
- Klea 61
- Klea 66
- AZ-50
- R134a

HP62 (identical in formulation to FX70) is recommended for use in all R502 applications, but only in **new** equipment. Klea 60 gives marginally higher efficiencies than Klea 61, but discharge temperatures higher than R502. Klea 66 and R134a both produce unacceptably high discharge temperatures. AZ-50 is intended for use in low and medium temperature R502 applications. This limits the choice of refrigerants in this category to Klea 60, Klea 61 and AZ-50. The complexity of retrofitting will vary with refrigerant, but in some cases will just involve changing to a POE oil and changing the expansion device and the filter/drier core.

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. In some cases, 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: (0905) 602 4700) and the HEVAC Association in the UK (Tel: (016285) 31186).

Figure 5: 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		AZ-50		HP62 FX70	
ASHRAE No.	R502		R407A		R407B		R407C		R507		R404A	
Manufacturer	Many		ICI		ICI		ICI		AS		DP/EA	
Status			Long term		Long term		Long term		Long term		Long term	
Drop-in			No		No		No		No		No	
Retrofit			Yes		Yes		Yes		Yes		No***	
Available			Yes		Yes		Yes		Yes		Yes	
	Tev (°C)		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**		**Tev (°C)**	
	-25	**-35**	**-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	0.96	1.00	0.95	0.98
COP	1.88	1.47	1.02	1.02	0.96	0.95	1.04	1.04	0.96	0.95	0.97	0.96
Pev (bar a)	2.41	1.61	2.10	1.35	2.41	1.57	1.92	1.22	2.62	1.75	2.63	1.75
Pco (bar a)	16.8	16.8	17.5	17.5	18.9	18.9	16.5	16.5	18.6	18.6	18.7	18.7
Tdis (°C)	74.5	81.9	87.3	96.5	73.7	80.1	92.2	102	67.1	67.2	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, AS: Allied Signal

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 retrofit

Retrofit of a frozen food cold store

Recently, a frozen food retailer converted a cold store at one of its outlets from R502 to R407b (a long-term alternative to R502 with a zero ODP). The cold store was fitted with two identical refrigeration systems; one was converted to the new refrigerant while the other was left to operate with R502 to allow a direct comparison. In each case Copeland single stage reciprocating compressors were used. The changes were made to the machine being retrofitted included replacement of the expansion valve, replacement of the dryer core to a type compatible with R134a, replacement of seals to types compatible with R134a. The mineral was then drained from the system and replaced with an ester based oil. The system was then repeatedly operated and the oil drained and replaced with fresh ester oil. This procedure was continued until the mineral oil content within the ester oil fell to below 1%. The next stage involved removing the R502 to containers ready for recycling. The system was evacuated and the R407b was added in the liquid phase, using the sight-glass as a guide. The superheat setting was optimised for R407b by adjusting the expansion valve. Each oil change took approximately one hour, while the removal of the R502, the evacuation and the recharging with the new refrigerant took about 4 hours.

Published results are not detailed. However, the following information was given:

- Instantaneous power consumption was lower for R407b than R502.
- The compressor operated for longer periods in the R407b system, but used less energy overall than the R502 system.
- The discharge temperatures were similar for both refrigerants.
- Similar refrigerating capacities were obtained for each refrigerant.

Case study - Energy efficiency

A Norlake Walk-in-Freezer used for the storage of serum at the J Hillis Miller Health Centre, University of Florida, Gaineville, Florida had to maintain a temperature -30 ºC with a maximum temperature of - 20 ºC .

The two chillers operating on R502 dump the extracted heat into the main chilled water circuit (8 ºC).

One chiller should have been on standby, but to achieve satisfactory operation the flow of chilled water to the condensers was restricted so that the head pressure was maintained at 15.5 bara and even at this condition flashing occurred in the required time. This reduced the system capacity so that it was no longer able to meet the requirement to maintain - 20 ºC with one chiller operating and one on standby.

A liquid pressure amplifier was installed and the head pressure was reduced to 8.2 bara. The capacity of the system increased by 58% and there was a 37% reduction in compressor amperage, reducing the energy consumption by 60%. The savings are exceptionally large in this case because of the use of chilled water as a dump. This does however show the potential for energy saving available in many systems by the removal of head pressure control.

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.