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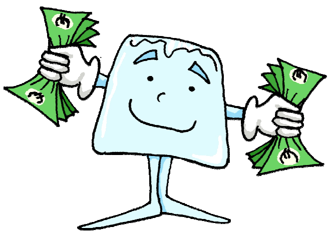

Guide 2

Purchase of Efficient Refrigeration Plant

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The Food & Drink Industry Refrigeration Efficiency Initiative

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Purchase of Efficient Refrigeration Plant

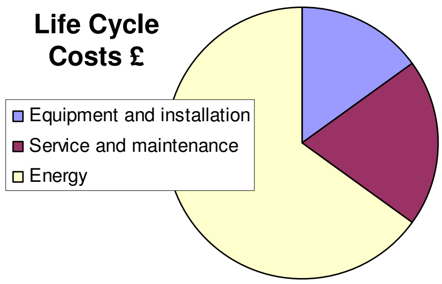
This guide will help to save you money if you are investing in new refrigeration plant. A plant designed for maximum efficiency:

1. Reduces energy costs and improves profitability
2. Reduces environmental impact, especially CO_2 emissions
3. Increases productivity due to increased reliability
4. Reduces service costs
5. Can reduce capital costs

1. Introduction

The specification of new capital plant can be complex. This is particularly true of refrigeration plant, which is not only costly in capital terms but which has a significant operational cost, primarily due to energy consumption. Refrigeration systems typically cost seven to ten times as much to run over their lifetime as they do to buy.

But it is possible to find refrigeration systems specified for the same application where the worst has double the energy use of the best.



The purpose of this document is to provide you with guidance on ensuring that energy efficiency is incorporated into the buying process. It will be of use to all those involved in the specifying and purchase of refrigeration plant, including site and facility managers, procurement managers and finance directors.

The greatest and easiest opportunity for maximising refrigeration plant operational efficiency is at the specification and purchase phase of its life

This Guide is one of a series of eight being produced under the Food & Drink Industry Refrigeration Efficiency Initiative, a project sponsored by the Carbon Trust and supported by the Food and Drink Federation, the British Beer and Pub Association, the Cold Storage and Distribution Federation, Dairy UK and the Institute of Refrigeration.

You do not need to be a refrigeration engineer to use this Guide. The technical terms used are explained in the glossary in Appendix 1 and sources of further information are given in Appendix 2.

2. Understanding and minimising the cooling load.

Before preparing a refrigeration plant specification the correct cooling load must be accurately assessed. This has a significant impact on the capital and operational costs of the plant. In addition accurate assessment ensures that the process or building, which the refrigeration plant is serving, operates effectively and reliably.

It is vital to take into account part load conditions at the design stage!

Many plants are designed by only considering the "design point" – i.e. the peak cooling load under the warmest ambient conditions. This is wrong as most plants only operate near the design point for a few days per year. It is important to optimise the efficiency of the plant under a wide range of relevant part load conditions.

- The plant must be sized to meet the design point peak load condition.
- BUT, the design should take into account the far more common operating conditions of reduced cooling load and lower ambient temperature.
- This can only be done if you properly assess the cooling load profile through the daily and seasonal variations in operation and ambient temperature.

There are two elements of cooling load - size and temperature - that impact most on refrigeration plant capital and operational costs. With regards to these elements it should always be remembered that:

- The bigger the cooling load the more expensive the plant
- The bigger the cooling load the more energy is used
- The lower the operating temperature the more expensive the plant
- The lower the operating temperature the more energy is used

In assessing the cooling load, you should consider where there may be existing inefficiencies and look for opportunities to reduce or remove these. The following 7 Case Studies give examples of common situations where refrigeration plant efficiency can be considerably improved by minimising the cooling load and optimising the interface between the cooling load and the refrigeration plant.

Case 1 – Ambient Free Cooling

The removal of all or part of a process load through pre-cooling with an ambient source, e.g. air or cooling tower water. The load reduction will probably be weather dependent, i.e. greater reduction in winter than in summer.

Example – Hot product coming off cookers / fryers / ovens at 50ºC plus, being cooled to lower temperatures in a blast chiller, using refrigeration plant.

Solution – Pre-cool with an ambient air blast to, say, 30ºC, reducing the load by over 50%.

What to look for at site – Hot process streams being cooled by refrigeration

Case 2 – Process Free Cooling

The removal of all or part of a process load through heat exchange with a process stream that needs heating up.

Example – Brewery, dairy, soft drink and distilleries where there are hot and cold process streams operating simultaneously.

Solution – Install or improve regenerative heat recovery using plate heat exchangers.

What to look for at site – Cold process streams that require heating.

Case 3 – Reduction or Removal of Unnecessary Process Heat Loads

The removal of all or part of a process load that does not require refrigeration.

Example – A treated water stream is cooled to 1ºC and then used as a "convenient" stream for a process that could easily use ambient water.

Solution – Remove high temperature stream requirement from the chilled system.

What to look for at site – Cooled streams being split and used for two or more purposes, one or more of which does not require such a low temperature.

Case 4 – Reduction of Non-Process Heat Loads

The reduction of an "auxiliary" heat load: such as insulation, air ingress, defrost, pumps or fans.

Example 1 – Fixed speed drive motors on fans and pumps delivering chilled fluids to processes.

Solution 1 – Fit VSD to pumps, to match fluid flow to process load, and fit VSD to evaporator fans to reduce air flow. Both will reduce input power to drive motors and heat load to refrigeration plant.

Example 2 – Doors into chill and cold stores left open longer than necessary.

Solution 2 – Improve control of store door opening and / or fit dehumidification plant, reducing the ingress of warm air and moisture.

What to look for at site – List all non-process loads, reviewing them to identify if they can be reduced.

Case 5 – Modification of Temperature Levels

Looking at whether cooling temperature levels are set to the highest possible value. This can apply to the process itself or to a secondary fluid. Remember every 1ºC the cooling temperature can be increased will improve efficiency by 2% to 4%.

Example 1 – Chill store set at 2ºC when 4ºC would suffice.

Solution 1 – Reset thermostat to 4ºC, improving efficiency by 4% to 8%.

Example 2 – Product leaving blast freezer colder than the cold store temperature in which it.

Solution 2 – Increase the blast freezer evaporating temperature to allow product temperature to match the cold store temperature.

Example 3 – Chocolate being solidified and cooled from 30ºC to 10ºC with glycol at -1ºC.

Solution 3 – Increase glycol temperature set point.

What to look for at site – Question temperature settings on all process loads and storage rooms. Also check if the actual temperature matches the thermostat setting – if the thermostat is inaccurate or badly positioned the temperature could be too low.

Case 6 – Avoiding "Lowest Common Denominator" Cooling

On large "common" systems, the evaporating temperature must be low enough for the coldest load – this is the "lowest common denominator – while other loads can run at much higher temperatures.

Example 1 – Cold store, at -25ºC, and associated loading dock, at 0ºC, run off the same refrigeration system, evaporating at -32ºC.

Solution 1 - Provide separate refrigeration plant for the loading dock cooling load, or if an economiser / intercooler is fitted to existing refrigeration plant, assess if the loading dock load can be met from this.

Example 2 – A brewery operates with glycol at -5ºC. Lowest temperature load is the beer cellar, to be held at -1ºC. But large loads include process water cooling from 20ºC to 10ºC.

Solution 2 – Provide separate packaged chiller plant to meet the higher temperature cooling load.

What to look for at site – Compare cooling load temperatures on common systems and check that they are compatible.

Case 7 – Splitting Loads with a Large Temperature Range

Some process streams are cooled over a wide temperature range, e.g. from 50ºC to -20ºC. This cooling load should be split across several cooling stages to maximise efficiency.

Example 1 – A food factory processes food from a fryer, coming out at 90ºC and being frozen to -18ºC, using 3-stages of cooling. The first stage utilises process water at 12ºC to take the product to 50ºC. The second stage operates at 0ºC evaporating, but connected to the third stage suction at -35ºC, using back-pressure regulators to control it.

Solution 1 – Provide a new second stage cooling plant, or if an economiser / intercooler is fitted to existing refrigeration plant assess if it can take the second stage cooling load.

Example 2 – Process water in a brewery is cooled from 20ºC (in the summer) to 4ºC in a single stage.

Solution 2 – Consider splitting this into two stages, from 20ºC to 12ºC and from 12ºC to 4ºC.

What to look for at site – Look for cooling loads with a wide temperature range and consider the options for splitting this.

3. Key elements of an efficient plant

1. Minimising cooling loads.
2. Maximising system efficiency at the prevalent load and ambient.
3. Optimising running conditions.
4. Selecting and matching refrigeration system components for efficient operation. This includes the refrigerant.
5. Providing sufficient control and monitoring equipment.
6. Installing and commissioning the refrigeration plant properly.
7. Using heat recovery, free cooling and thermal storage opportunities where appropriate.

3.1 Minimising cooling load

Cooling loads on refrigeration systems arise either directly, from the product or space being cooled, or indirectly, from parasitic heat loads. In both cases these should be minimised as far as possible. Section 2 provides a number of case studies explaining this. Appendix 3 defines and lists common parasitic loads.

3.2 Maximising Efficiency at the Prevalent Load & Ambient

Understanding the load profile of the process to be cooled can have a major impact on the efficiency of a refrigeration plant. While plant will be sized to meet the cooling load at the maximum load and in the maximum summer ambient temperature, these conditions generally occur for only a very limited period of time. Understanding the load profile allows a refrigeration plant to be designed for maximum efficiency at the most prevalent conditions, by, for example:

- Allowing the compressor discharge pressure to float with ambient as much as possible.
- Selecting an appropriate number of compressors to maintain high compressor loading and consequently efficiency.
- Fitting variable speed drive units to compressors, pumps and fans.

3.3 Optimising running conditions

Best efficiency will be achieved if plant is running at optimal conditions. Keeping the difference between system evaporating and condensing temperatures to a minimum by using close heat exchanger approach temperatures is important.

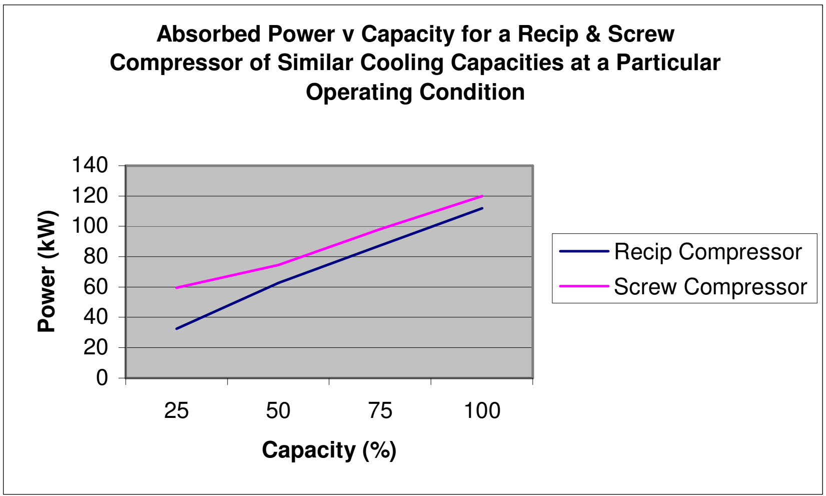
Therefore to optimise running conditions

- Match evaporating temperatures to cooling temperature requirements.
- Keep the design condensing temperature as low as possible.
- Do not use compressor discharge pressure, i.e. head pressure, controls, until needed. It is very common to find plants operating at unnecessarily high head pressure because of poor control settings.
- Use a good control system.

3.4 Ensure that system components are selected for efficient operation

The correct selection of components will have a major effect on refrigeration plant efficiency. Proprietary refrigeration plant offers little flexibility in terms of energy efficiency. Bespoke plant provides the potential to maximise energy efficiency as components can be specifically chosen to best suit the cooling requirement.

- The most suitable compressor(s) for the size of load and the operating conditions.
- Compressors with good part load characteristics, multi compressor systems with good control systems or compressors fitted with variable speed drives can be used to maximise efficiency at low or part loads. For example:



At the defined operating condition this example indicates that the reciprocating compressor would deliver better performance both at the 100% design capacity and at part load operation.

- The most suitable condenser type for the application can be selected, e.g. evaporative, air-cooled or water-cooled.
- Evaporators and condensers can be selected to maximise the evaporating temperature and minimise the condensing temperature (i.e. are large enough).
- The most efficient auxiliary fans and pumps can be selected.
- Good control systems can be used to optimise overall performance and efficiency.
- Refrigerant type

3.5 System control and monitoring

A refrigeration system will maintain efficient operation if it can respond to changes in operating conditions and if operators can observe and measure its operating parameters. This can only be achieved through the use of an effective control and monitoring system. The control system should be programmed to maximise efficiency under all anticipated operating conditions. It should be controlling to achieve:

- An evaporating temperature that is as high as practicable
- A condensing temperature that is as low as practicable
- Appropriate control of multi-compressor installations
- Matching of refrigeration plant capacity to process cooling loads

The monitoring system should provide the feedback to plant operators, either confirming that this is being achieved or allowing them to identify the causes of plant performance deterioration. The feedback information should typically include:

- Time and date
- Plant operating pressures and temperatures
- Compressor hours run in total
- Hours run
- Number of compressor starts in a defined period
- Compressor current
- Instantaneous power consumed per compressor and auxiliaries, ie fans & pumps
- Power consumed in the previous calendar day by compressors & auxiliaries
- The status of various plant items, eg compressor part load operation

In addition confirmation of plant performance and trouble-shooting can be greatly enhanced by the provision in the monitoring system of:

- Trend-graphing of the data above
- Fault and event logging
- Alarming
- Display of graphical mimics

3.6 Installation, commissioning and record keeping

Efficient plant will have been properly installed and commissioned before use and detailed records should be stored and available for perusal, if required. The installation process is critical to attaining efficient plant operation, and care should be taken to ensure that:

- Pipework connecting all the main components is properly sized, routed and insulated; to minimise pressure drops, prevent liquid locking, reduce heat loss and ensure a long plant life.
- Pressure and leak testing is carried out properly.

- The refrigeration system is properly evacuated to remove air and moisture, prior to charging with refrigerant
- The correct charge of refrigerant is introduced.

Good commissioning will include checks on cooling performance and efficiency, detailed in a commissioning report. Records to be kept on site with the equipment should include:

- Commissioning report
- Technical drawings and specifications
- Operating manuals

3.7 Heat recovery and thermal storage.

A system can achieve greater efficiency if opportunities for heat recovery, free cooling and thermal storage are identified and taken advantage of.

These opportunities include:

- Recovered heat from the compressor discharge or condenser can be used to heat water or heat a room. The heat available is of two types:
    - High grade, coming from de-superheating refrigerant discharge gas, which can be anywhere from 60^{O}C to 90^{O}C. The actual quantity of heat available from this source is relatively small, typically 5% to 10% of the total heat being rejected by the refrigeration system.
    - Low grade, coming from the saturated refrigerant being condensed, which can be from 20^{O}C to 40^{O}C.

  This is an opportunity that is well worth investigating, as otherwise all the heat from the system will be rejected to ambient and lost. However, there are potential pitfalls that should be taken account of in assessing if heat recovery is worth implementing. The most common pitfall is requiring the control system to maintain artificially high condensing pressures and temperatures, to benefit the heat recovery. This prevents implementation of the major energy saving opportunity on the compressor, namely floating the compressor discharge pressure as the ambient falls.

  New technology and techniques are available that increase the potential for effective and efficient application of heat recovery. Examples of this include fitting a small parallel compressor in the system to boost a portion of the discharge gas for heat recovery and the availability of trans-critical CO2 heat pumps which can simultaneously provide high grade hot water at 60^{O}C to 70^{O}C and chilled water at 4^{O}C to 6^{O}C, with high combined efficiencies.

  Examples of effective heat recovery systems include underfloor heating of cold stores, space heating of factories and pre-heating of boiler feed water.

- Thermal storage is a technique that can sometimes improve a plant design. Cold is stored (e.g. by making ice) during part of the day and that cold is used at a later time. Thermal storage has one of the following benefits:
    1. If the cooling load profile is very “peaky”, cold can be stored during a period of low load and used to provide cooling during a peak load. This means the main plant is smaller, which produces capital cost savings and may avoid long periods of low load operation of a big plant (which is usually inefficient).
    2. Night time thermal storage can be used to store cold during periods with low electricity tariffs. This might not save energy, but can save operating costs. It may deliver carbon emissions benefits as it allows for higher utilisation of base load electricity generation and can take advantage of the lower night time ambient temperatures to float compressor discharge pressures down.

For loads above 0^{o}C ice an ice bank is usually the most convenient form of thermal store. Below 0^{o}C it is possible to use other types of fluid that freeze at a suitable temperature.

4. Specifying and Purchasing New Refrigeration Plant

The refrigeration plant specification should provide the operational requirements for the refrigeration plant, for sizing and selection of equipment. The operational requirements are based on the assessment of the cooling load and the responsibility for providing accurate data, ie the appropriate loads and temperatures, lies with you. In addition the specification should incorporate information that defines:

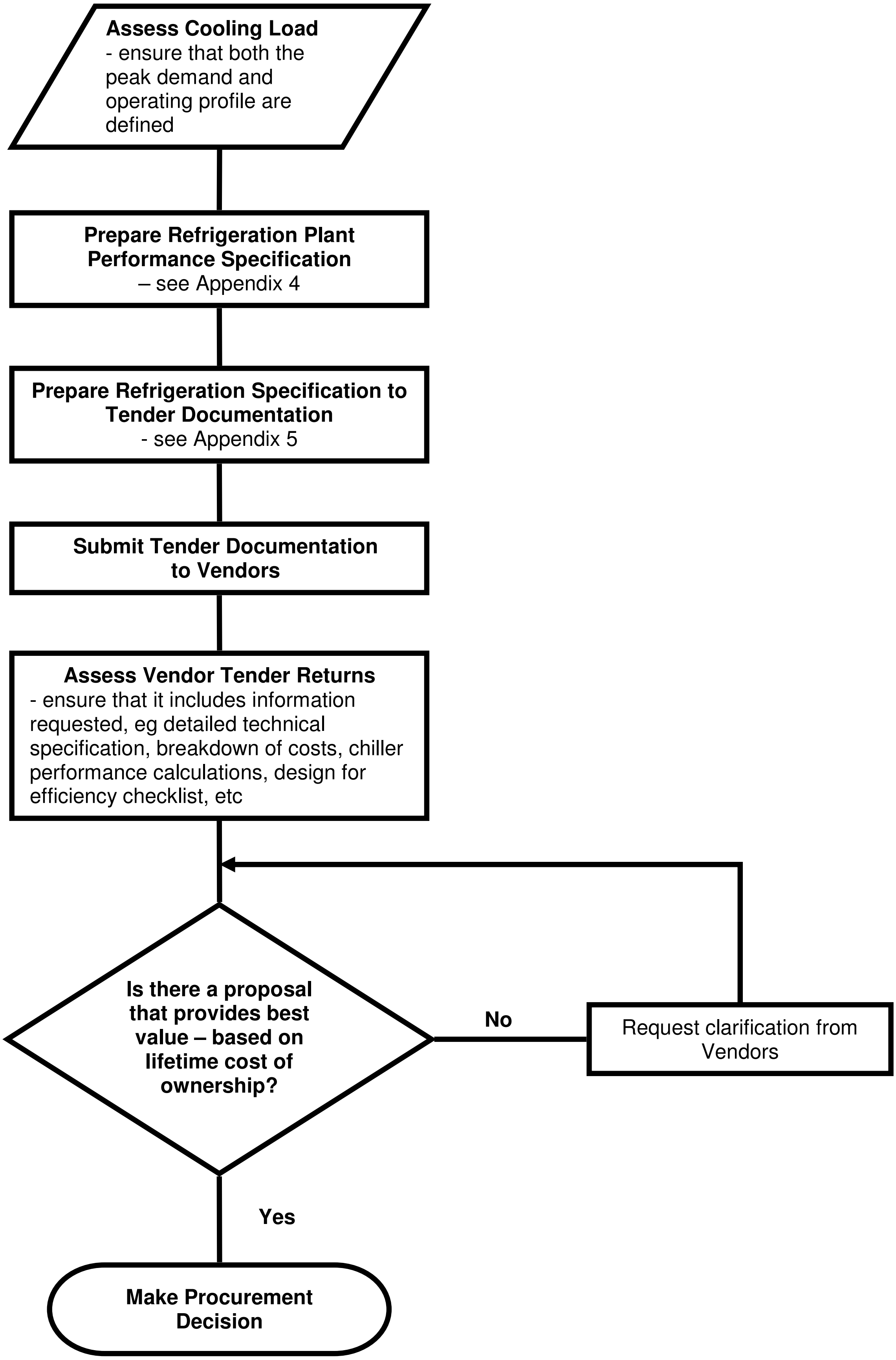
- Compliance with design and build standards
- Scope of supply
- Energy efficiency
- Life cycle costs
- Environmental impact
- Information to be submitted with the tender
- Purchaser's responsibilities
- Performance assessment
- Maintenance needs

REMEMBER - The greatest and easiest opportunity for maximising refrigeration plant operational efficiency is at the specification and purchase phase of its life

Appendix 4 is a Refrigeration Plant Performance Specification Checklist, which allows you to confirm that you have taken account of those elements of refrigeration plant performance that impact most on efficiency.

Appendix 5 is a Refrigeration Plant Specification to Tender Checklist, which allows you to confirm that you have included enough information to allow a Vendor to provide a comprehensive and consistent tender package.

Below is a flowchart which describes the steps which should be gone through in the process of specifying and procuring new plant:


Assess Cooling Load
- ensure that both the peak demand and operating profile are defined
Prepare Refrigeration Plant Performance Specification
– see Appendix 4
Prepare Refrigeration Specification to Tender Documentation
- see Appendix 5
Submit Tender Documentation to Vendors
Assess Vendor Tender Returns
- ensure that it includes information requested, eg detailed technical specification, breakdown of costs, chiller performance calculations, design for efficiency checklist, etc
Is there a proposal that provides best value – based on lifetime cost of ownership?
No
Request clarification from Vendors
Yes
Make Procurement Decision

5. Lifetime Cost of Ownership – an accurate way to compare options

Typically, refrigeration systems cost 7 to 10 times as much to run as they do to buy

It is possible to find refrigeration systems specified for the same application where the potential difference in energy usage can be between 20% and 50%

When buying new refrigeration plant consideration should be given to the lifetime cost of ownership. That is, in addition to the capital cost of buying the refrigeration plant, the Purchaser should, in his assessment of alternative proposals, compare their operational costs. These operational costs will include: energy, maintenance and other associated costs. Other costs could include the purchase of water and water treatment chemicals for "wet" heat rejection systems and the disposal costs of effluent from bleed-off on cooling towers and evaporative condensers.

In preparing the specification for a new refrigeration plant, the Purchaser should detail the information they expect to receive with a tender submission. To ensure compliant tender submissions and comparative operational data the Purchasers needs to define the process cooling load, its profile and operating temperatures. In terms of the requirement from Vendors, they must provide enough information to allow a lifetime cost of ownership model to be developed. Included should be:

- **Capital Cost for the Proposed Refrigeration Plant.**

  This should include a breakdown of the costs that make up the headline price for the submission

- **Performance Calculations**

  This should include all power consumers in the refrigeration plant, ie compressor drive motors and all ancillaries eg pump and fan motors. The calculations should be based on the process cooling load, its profile and the operating temperatures provided by the Purchaser.

  The Purchaser should consider providing a performance calculation template that all vendors return. This will ensure consistent data for inclusion in the lifetime cost of ownership model.

In carrying out the assessment of the lifetime cost of ownership there are a number of financial investment appraisal models that could be used. These include:

1. Payback period
2. Net present Value (NPV)
3. Return on Investment (ROI)
4. Internal rate of return (IRR)

Of these the most widely used are assessments based on the payback period and NPV.

Payback Period

The payback period assessment looks at length of time taken to repay the initial capital cost. Its primary benefit is that it is simple to use. It is effective if:

- The payback is anticipated to be short, ie typically less than 3 years.
- The various costs, ie capital and energy, are accurately known.
- The cost streams are not time related.

The equation for calculating the payback period is then:

$$\text{Payback (in years)} = \frac{\text{Capital Cost of Equipment (incl installation \& commissioning)}}{\text{Operational Cost (per annum)}}$$

Net Present Value

This method takes account of all costs associated with owning a piece of capital plant and discounts the future costs associated with operating the system, ie energy, maintenance, water, chemical and replacement, using the cost of capital, ie interest rate, as the appropriate discount rate. The basis of this approach is for an NPV analysis to be carried out on each of the proposals being considered. The decision rule is that whichever option offers the lowest NPV will have the lowest lifetime cost of ownership. The model allows the person carrying out the comparison to vary the interest rate and the anticipated lifetime.

The advantages of this method of financial assessment over others are that it:

- takes account of the time value of money, by discounting the cash flows arising in the future
- takes account of all relevant cash flows
- allows different interest rates and time periods to be modelled.
- provides a clear decision rule concerning acceptance/rejection of a particular option
- is consistent with the objective of maximising shareholder wealth, which is assumed to be the primary objective of a business.

Appendix 6 is an NPV model template for a refrigeration system.

Appendix 1: GLOSSARY

Ambient Free Cooling	Using a “free” stream such as ambient air or water from a cooling tower or other source (e.g. a river or borehole) to cool a product without needing a refrigeration plant.
Blast freezer	A system used to freeze products using a blast of fast moving cold air.
Cooling load	The total amount of cooling carried out by a refrigeration plant – usually made up of several individual heat loads.
Design point	The peak operating conditions for which a refrigeration plant is designed – usually at peak cooling load and maximum summer time ambient temperature.
De-superheating (refrigerant discharge gas)	Removing heat from hot refrigerant vapour leaving a refrigeration compressor prior to the point at which the vapour begins to condense.
Discounting	This is the discount rate or interest rate used in NPV calculations.
Heat recovery	Collecting the waste heat being rejected from a refrigeration plant and using it to heat water, a product or a building.
Internal rate of return (IRR)	A financial appraisal tool (see NPV).
Net present Value (NPV)	A method of showing the financial benefit of an investment, generally considered to be a more sophisticated method than payback period.
Payback period	The time taken to payback an investment (usually expressed as capital cost divided by annual cost benefit).
Plate heat exchangers	A type of heat exchanger often used to heat or cool liquids
Process Free Cooling	Using a cold product that requires heating to cool down another warm product that needs cooling via a heat exchanger system.
Process stream	A product or ingredient that requires heating or cooling.
Return on Investment (ROI)	A financial appraisal tool (see NPV).
Thermal storage	Using a substance to store cold that has been produced by a refrigeration plant for use at a later time. For example making ice and then using the ice to cool a product at a later time.
VSD	Variable speed drive – a device that changes the speed of an electric motor.

Appendix 2: SOURCES OF FURTHER INFORMATION

Food and Drink Federation	Trade association for food and drink manufacturers.	www.fdf.org.uk
Institute of Refrigeration	Professional body for refrigeration and air conditioning engineers.	www.ior.org.uk
British Beer and Pub Association	Trade association for brewing and pub sector.	www.beerandpub.com
Dairy UK	Trade association for dairy sector.	www.dairyuk.org
Cold Storage and Distribution Federation	Trade association for the temperature controlled supply chain.	www.csdf.org.uk
British Refrigeration Association	Trade organisation for companies in the refrigeration and air conditioning industry.	www.feta.co.uk
Carbon Trust	Information and support regarding climate change issues.	www.carbontrust.co.uk
Guide 1	Appointing and managing refrigeration contractors.	www.ior.org.uk
Guide 2	Procurement of new plant	www.ior.org.uk
Guide 3	Checklist for operational improvements.	www.ior.org.uk
Guide 4	HCFC phase out and F gas regulations.	www.ior.org.uk
Guide 5	Reducing heat loads.	www.ior.org.uk
Guide 6	Avoiding high head pressures.	www.ior.org.uk
Guide 7	Improving part load performance.	www.ior.org.uk
Guide 8	Reducing auxiliary fan and pump power.	www.ior.org.uk
EN378	Refrigerating systems and heat pumps. Safety and environmental requirements.	www.bsi-global.com
Refrigeration and Air Conditioning	Comprehensive text book covering all aspect of refrigeration and air conditioning.	ISBN 0-13-323775-3
GPG 278	Purchasing efficient refrigeration – the value for money option.	www.carbontrust.co.uk www.ior.org.uk
GPG 279	Running refrigeration plant efficiently – a cost saving guide for owners.	www.carbontrust.co.uk www.ior.org.uk
GPG 280	Energy efficient refrigeration technology – the fundamentals.	www.carbontrust.co.uk www.ior.org.uk
GPG 347	Installing and commissioning of refrigeration systems.	www.carbontrust.co.uk www.ior.org.uk
GPG 364	Service and maintenance technicians guide.	www.carbontrust.co.uk www.ior.org.uk
RAC	Monthly subscription trade journal and year book.	www.emap.com

Appendix 3: PARASITIC LOADS

Parasitic loads are loads on a refrigeration system from items other than those which it is the intention to cool. Many parasitic loads use energy twice – directly in the electrical power required to drive fans and pumps and indirectly through additional heat gain which must be removed by the refrigeration system.

Examples of Parasitic Loads	Opportunities to Minimise / Reduce the Parasitic Loads
Fans & pumps	Use efficient fans & pumps, fit variable speed drives and run only when necessary.
Lighting	Use energy efficient lighting and turn off when not required.
Personnel In cold stores	Keep occupancy in the cold space to a minimum.
Air changes, caused by open doors in cold & chill store, make up air needs, etc	Minimise air changes in the cold space by good practice, eg door management, use of dehumidification plant, etc.
Heat gains through insulation	Have insulation checked regularly and replace when required.
Machinery in cold spaces, eg fork lift trucks	Limit the use of machinery in the cold space.

Appendix 4: REFRIGERATION PLANT PERFORMANCE SPECIFICATION CHECKLIST

The following checklist should be used when preparing a Specification to Tender document, to ensure the appropriate operational requirements have been fully listed. It can only be prepared once a detailed assessment of the cooling load has been undertaken.

The purpose of the Refrigeration Plant Performance Specification is to define the plant operating conditions, to ensure that Vendors select major plant components consistently, with due regard for operational efficiency.

As a general guide:

1. For a fluid cooling evaporator, good practice would set the refrigerant saturated suction temperature at between $4^{O}C$ and $5^{O}C$ below the fluid temperature off the chiller, ie if you are wanting water OFF the chiller at $+6^{O}C$, the saturated suction temperature would be defined at between $+1^{O}C$ and $+2^{O}C$.

2. For an air-cooling evaporator, good practice would set the refrigerant saturated suction temperature at between $6^{O}C$ and $8^{O}C$ below the air ON temperature to the air cooler.

As a general guide, for the various condenser types, good practice would set the saturated discharge temperature at:

- Water cooled condenser $3^{O}C$ - $5^{O}C$ above water off condenser temperature
- Air-cooled condenser $10^{O}C$ to $15^{O}C$ above design ambient dry bulb temperature
- Evaporative condenser $10^{O}C$ above design ambient wet bulb temperature

At wider approach temperatures the condenser and evaporator will be smaller and less expensive but the system will cost more to run. There may be occasions when the good practice figure cannot be used, for example, where there are space constraints on site that require the condenser is selected on size rather than performance.

Item	Description	Comment	Included Y/N
1	Outline scope of supply	Define the range of equipment and project requirement: design, manufacture, supply, install and commission.	
2	Refrigerant type	This can include HFCs, ammonia, CO_2 and hydrocarbon refrigerants. **You should make this decision**.	
3	Refrigeration capacity (kW) – design conditions	**You need to have carried out an appropriate assessment of this.**	
4	Refrigeration capacity (kW) average conditions	Providing this allows the vendor to offer alternative designs that will be more energy efficient.	
5	Minimum saturated suction temperature (^{O}C)		
6	Maximum saturated discharge temperature (^{O}C)		
7	Type of evaporator	Typical for fluid cooling are shell & tube, plate & plate and plate & shell units. Typical for air cooling are finned coil units.	
8	Evaporator material	This may be relevant depending on application and fluids being chilled.	
9	Secondary fluid to be chilled	Includes air if cold or chill store application. If fluid is liquid other than water, ensure the strength of mixture, eg 30% ethylene glycol, is suitable for the operating temperatures required.	
10	Secondary fluid temperature ON to evaporator (^{O}C)	See guidance notes at beginning of Appendix 3.	

Item	Description	Comment	Included Y/N
11	Secondary fluid temperature OFF from the evaporator	The lower this is the larger and less efficient the system will be.	
12	Maximum allowable pressure drop of secondary fluid through the evaporator	This will depend on a number of factors, but for liquids good practice will limit to between 0.5bar and 1.0 bar.	
13	Type of Condenser	The type selected for a project will depend on a number of factors. Small cooling loads, typically below 500kW are normally served by air-cooled condensers while larger loads by water cooled or evaporative condensers.	
14	Water temperature ON to condenser	Only applies to water-cooled condensers.	
15	Water temperature OFF from condenser	Only applies to water-cooled condensers.	
16	Maximum allowable pressure drop of secondary fluid through the condenser	Only applies to water-cooled condensers. Value will depend on a number of factors, but good practice will limit to between 0.5bar and 1.0 bar.	
17	Ambient design dry-bulb temperature	Required for air-cooled condenser selection.	
18	Ambient design wet-bulb temperature	Required for evaporative condenser selection.	

Appendix 5: REFRIGERATION PLANT SPECIFICATION TO TENDER CHECKLIST

The quality of information provided to the Vendor in a Request for Tender document is vitally important in ensuring that the proposal submitted and ultimately the equipment installed makes due allowance for efficient operation. It should also enable you to accurately compare tenders and select the best option. In general terms the following should be included in the Request for Tender:

Introduction

An outline of the project purpose, and general requirements, plant location, zoning requirements, future expansion needs, and performance expectations, eg the requirement for minimum life cycle cost

Refrigeration Plant Performance Specification

Definition of the refrigeration plant operating conditions, including design and average data if applicable and the operating limits on the primary refrigerant circuit, as outlined in Appendix 3.

General Installation and Equipment Specifications & Standards

This should define the standards and codes that the refrigeration plant should be designed, built, installed and operated in accordance with. It could include customer specific requirements, for example on site specific pipework, insulation and electric standards.

Scope of Supply

This must list the responsibilities the Vendor. It should also list aspects of the project that will be dealt with by the Purchaser or 3rd parties

Specific Design / Project Considerations

This section should list specific issues that you want to ensure the Vendor takes account of. These may be technical, eg incorporating requirements for automatic oil recovery, describing the control system & philosophy, listing the operational data to be monitored by the control system, or more generally project related, eg listing the requirements for performance testing or submission of O&M manuals.

Information to be Provided with Tender

This should detail the minimum information that is expected with the tender submission. In addition it should detail the data you are providing to allow the Vendor to submit a compliant tender submission, for example process load data. Typically the tender information submitted by the Vendor should include:

- A detailed technical submission, including all major components and their operating conditions
- A breakdown of the costs that make up the headline price for the submission.
- Performance calculations, giving power usage at defined conditions for the system. All energy users in the refrigeration system must be included in these calculations. You should define how this is to be calculated and provide the cooling load information at the design condition and the most prevalent conditions.
- A completed Total Equivalent Warming Index assessment for the plant being offered, based on the British Refrigeration Associations guidelines.
- A cost of ownership assessment, based on a life cycle analysis model
- A statement of how “Design for Efficiency” has been incorporated into the design.

Documentation to be provided in Contract

The key documentation that should be provided by the Vendor includes:

- A programme of works, including details of the refrigeration plant build, site installation and commissioning phases.
- Drawings including: equipment site layout, primary refrigerant circuit, secondary fluid circuit, site layout and electrical wiring diagrams.
- An Operation & Maintenance Manual, which should include:

  Plant Performance Specification

  Detailed Equipment Schedules

  Electrical Specifications Description of Plant Operation

  Start-up, Shut-down, Maintenance and Emergency Procedures

  Appropriate Technical Instructions, eg motor alignment

  Certification Documentation, eg pressure vessel test certificates, system pressure test certificates

  Material Safety Data Sheets including refrigerants, oils and secondary fluids (eg glycols, brines, etc)

  Commissioning Documentation

  Plant Log Sheets

Appendix 6
NPV Comparison of Alternate Proposals

	Cost of Capital		8.00%								
	[redacted]										
	Asset's useful life		10	**Years**							
Option 1:	**Yr 0**	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Yr 6**	**Yr 7**	**Yr 8**	**Yr 9**	**Yr 10**
Investment Costs											
Salvage Cost of existing equipment (if replacement)	0										
Acquisition Cost	0										
Installation Cost	0										
Other (describe)	0										
Operating Costs											
Maintenance	0	0	0	0	0	0	0	0	0	0	0
Spares & Replacement Costs	0	0	0	0	0	0	0	0	0	0	0
Electricity Usage	0	0	0	0	0	0	0	0	0	0	0
Water & chemical usage	0	0	0	0	0	0	0	0	0	0	0
Salvage / Scrape Value	0	0	0	0	0	0	0	0	0	0	0
Other (describe)	0	0	0	0	0	0	0	0	0	0	0
Total Cash Flow	0	0	0	0	0	0	0	0	0	0	0
Running cost year by year	0	0	0	0	0	0	0	0	0	0	0
Running NPV	0	0	0	0	0	0	0	0	0	0	0