Benefits that flow from secondary systems

Secondary systems have been in the news as potential green solutions. But, it is vital to get the design right, says Zafer Ure

The recent environmental concerns over CFCs, HCFCs and, most recently, over HFC refrigerants, have forced designers to explore alternatives, among them indirect solutions.

In many refrigeration applications, heat is transferred to a secondary fluid, which can be any liquid cooled by the primary refrigerant and then used to transfer heat without changing state. These fluids are also known as heat transfer fluids, brines, or secondary refrigerants. They are also found in many new applications and in low temperature refrigeration, enabling the use of environmentally friendly primary refrigerant such as ammonia and hydrocarbons.

Indirect refrigeration systems can have some significant potential advantages over direct refrigeration systems. In an indirect system, for example, it is possible to design and manufacture factory-built compact refrigeration units with an extremely small primary refrigerant charge.

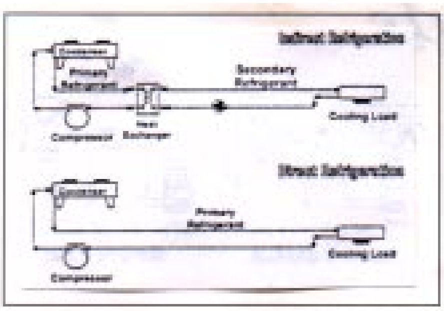
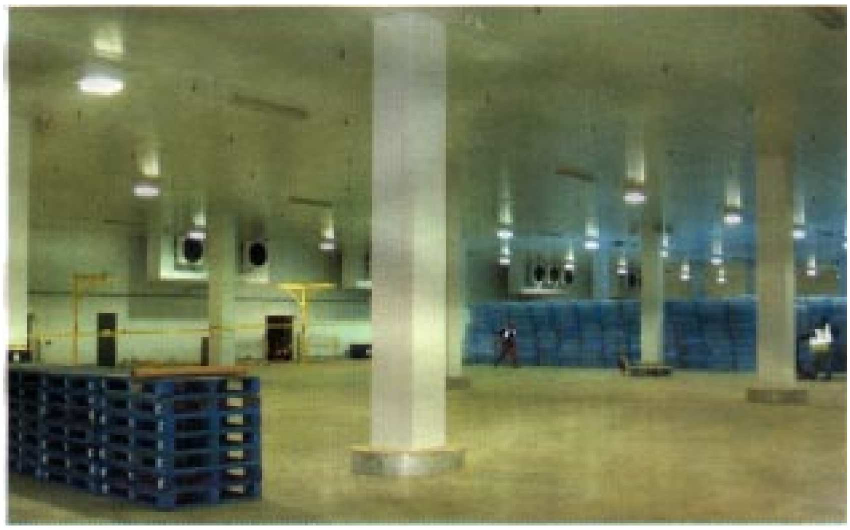


Figure 1: Direct Vs Indirect Refrigeration System

However, an indirect system with a secondary refrigerant circuit means an extra cost for the pump and heat exchanger with an added temperature difference. If a secondary refrigeration system is not designed correctly, this may lead to higher total energy consumption in comparison with a direct system.

Therefore, it is vital to choose the right secondary refrigerant for the application in order to provide an economical and energy efficient system.



Dairy Crest's new site is cooled by a secondary system employing Tyfoxit secondary coolant

In principle, water is an excellent secondary refrigerant for mainly air conditioning and other applications for temperatures down to around +3 °C.

The main problem, however, is to find suitable fluids for chilling and freezing applications below 0 °C. There are several fundamental requirements that any secondary refrigeration must satisfy:

1) Large refrigeration capacity using small temperature difference with minimum volume flow rate;

2) Small temperature difference in heat exchange:

3) Simple and smaller pumps

Furthermore, any secondary refrigerant must be compatible with commonly used materials in terms of corrosion and long-term stability. It is also vital to satisfy health and safety and environmental requirements.

Selection

The freezing point can be considered as the starting point to choose a secondary refrigerant, and it should be below the operating temperature of the system with a comfortable safety margin.

The thermophysical properties of secondary refrigerants are also very important. It is essential to find the right balance between the viscosity, specific heat and thermal conductivity for optimum design efficiency.

Some of the most important parameters are corrosivity, environmental pollution, toxicity, and flammability, handling security and cost levels.

The commercially available secondary refrigerants can be divided into two categories, aqueous (i.e. water based) and non-aqueous solutions.

Aqueous solutions are mixtures of various salts and waters. The mixtures of such compounds as magnesium and calcium chloride has been used extensively since the early days of refrigeration. More recently, mixtures of potassium acetate and potassium formate have been introduced to the market to overcome some of the corrosion and thermophysical property problems of the old mixtures, in particular for low temperature applications.

Non-aqueous liquids are marketed under many different brand names and they have comparatively poor heat transfer ability and transport capability.

Continued on page 34

Continued from page 32

They are also quite expensive and have practical application problems in terms of cross contamination, corrosion and operating pressures.

Properties

When comparing different secondary refrigerants it is vital to evaluate the combination of freezing point, viscosity, specific heat and thermal conductivity as a whole. Other thermal properties are the boiling point, thermal volume expansion and the surface tension.

Freezing point can be described as the crystal formation point whereby the liquid turns from fluid to solid. It is common practice to choose a fluid with the freezing point at least 5- 10 °C below the system operating temperature.

A low boiling point can be a problem for applications where the operating temperature of the liquid may exceed the boiling point even at relatively low temperatures when exposed to atmospheric air, as in the case of open systems.

Surface tension can be described as the force per unit length that strives to keep the surface as small as possible. A low surface tension may increase the tendency of the solution to leak out; it may also increase the risk of foaming within the system and result in pump cavitation.

Density is based on the concentration levels and is considered one of the easiest and main ways of checking the concentration level.

Viscosity is a very important factor for sizing the pipes and pumps. Hence, viscosity should be acceptable at the operating temperature of the secondary refrigerant for an economical installation both for the initial installation and day to day running cost points of view.

Specific heat capacity should be as high as possible in order to reduce the flow rate needed for a given cooling load. The lower flow rate leads to smaller volume flow requirement and consequently, smaller pipes and pumps.

Thermal Conductivity should be as high as possible in order to provide a good heat transfer efficiency and thereby decreasing the temperature difference between the liquid and tube wall.

Thermal volume expansion is also an important element for the application. It dictates the size of the expansion vessel for the system.

Tyfoxit cools Dairy Crest Site

One of the largest Tyfoxit secondary refrigerant applications has been installed at Dairy Crest's new factory near Nuneaton, Warwickshire.

Installer SPL Refrigeration worked with consultant Michael Boast Associates, who chose Tyfoxit instead of conventional Food Grade Propylene Glycol for this chilled food process application in order to reduce the system pressure drop, "effectively reducing daily costs by means of minimising pump energy".

Penalty

The high heat transfer properties of Tyfoxit offered the designers cost effective smaller coolers, reducing the fan heat penalty.

The system is based on a common ammonia primary refrigerant with Tyfoxit secondary solution for chilled food circuits serving both production and cold storage areas back-up both during initial charging and follow-up supplies.

The system was fully commissioned in the middle of October 1999 and is reported to be operating satisfactorily.

Options

Most commonly used secondary refrigerants are listed in tables 1 and 2.

The majority of aqueous solutions are based on salt mixtures and they are relatively corrosive by nature. Therefore, it is vital to stabilise these solutions by means of corrosion inhibitor packages and chemical stabilisers for a long-term use.

Description	Concentration (% v/v)		
	Freezing Temperature (°C)		
	-15 °C	-30 °C	-40 °C
Ethylene Glycol/Water	30.5	45.4	52.8
Propylene Glycol/Water	33	48	54
Ethyl Alcohol/Water	24.5	40.9	53.1
Methyl Alcohol/Water	20	33.6	41
Glycerol/Water	39.5	56	63
Ammonia/Water	10.8	17.7	21.1
Potassium Carbonate/Water	27	36.6	25.4-
Calcium Chloride/Water	17.9	25.4	28.3
Magnesium Chloride/Water	14	20.5	-
Sodium Chloride/Water	18.8	-	-
Potassium Acetate/Water	24	34	39
Potassium Formate/Water	24	36	41

Table 1. Aqueous secondary refrigerant solutions

Description	Freezing Temperature (°C)
Diethylbenzene Mixtures	-73
Synthetic Hydrocarbon Mixtures	-85
Hydrofluoroether	-43
Polydimethylsiloxane 1	-100
Polydimethylsiloxane 2	-93
Citrus Oil Solution	-96
Carbon Dioxide	-56.7
Alkylated Benzene	-148
Alkyl Substituted Aromatics	-103.5
Ester Based Solutions	-62
Aliphatic Hydrocarbon	-85

Table 2. Non-aqueous secondary refrigerant options

Some dilute solutions will also require the addition of biocides to prevent microbiological fouling. It is important to choose a secondary refrigerant with a long track record for the intended temperature range.

Design

There are two common techniques applied to utilise secondary heat transfer fluids, namely open and sealed systems, as illustrated.

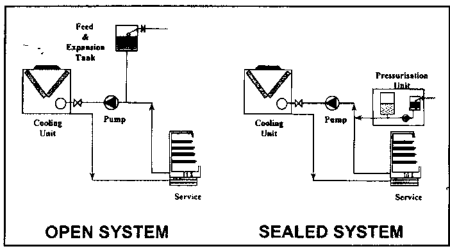


Figure 2: Circulation system types

Both systems are widely applied throughout the world. Some of the advantages and disadvantages are summarised in the accompanying table.

Viscosity and Specific Heat Capacity: Viscosity strongly influences the type of flow that occurs inside the heat exchanger. It also has a significant impact on the pipework pressure drop.

However, higher specific heat capacity reduces the mass flow requirement for a given cooling load with identical system circulation temperature differences. System volume flow requirement can be obtained by dividing the mass flow rate by the density.

Considering very close density values for the majority of the salt based solutions, higher specific heat capacity solution

Continued on page 36

	Open System	Sealed System
Advantages	Simple Cost effective design No pow er supply	Freedom of location Air free operation Positive pump suction protection
Disadvantages	Air contamination Solid containination Health & safety concerns Tank must be installed above the pump suction to match NPSH	Installation cost Annual maintenance Small pow er consumption

Table 3: Open versus sealed system design

Continued from page 34

leads to smaller volume flow rates.

Low viscosity may not necessarily offer smaller pipes and less pressure drop for the system as a whole if it has a very poor specific heat capacity.

Therefore, it is vital to strike a balance between the specific heat capacity and viscosity of the fluid for the intended operating temperature range, in order to achieve optimum pipe velocities.

Heat Transfer: The Reynolds number dictates the type of flow for the pipework and in return the heat transfer rate is calculated based on the flow regime.

Materials Compatibility: It is vital to cheek all system components' compatibility with the intended secondary refrigerants. The majority of the chloride based solutions attack metal, and both potassium acetate and potassium formate attack zinc.

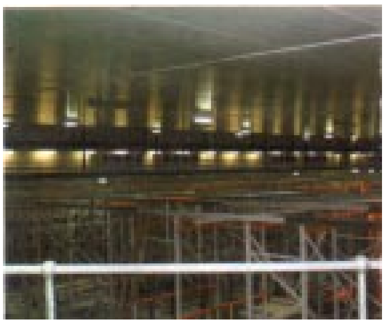
Hence, any material containing zinc, such as galvanised surfaces, should be avoided.

Maintenance: A full maintenance programme must be incorporated as part of the design in order to ensure that the concentration level as well as the fluid corrosion protection ability is maintained throughout the useful life of the fluid.

Health and safety issues: For applications where human contact is a possibility, or for food applications, it is best to consider non-toxic flu
ids such as organic salts, propylene glycol and glycerol.

Conclusion

It is clear that no single secondary refrigerant is ideal for every type of application, and therefore designers must find the best solution for the application on a job by job basis based on temperature range.



Scale is not a big consideration

Aqueous solutions generally require less volume flow in comparison with non-aquesolutions, in order to transport the identical cooling capacity.

Designers must compare the corrosivity, environmental pollution, toxicity, and flammability, site handling and cost issues along side the thermophysical properties of, the intended secondary refrigerants.

**A full technical manual is available from the author. For more details contact Zafer URE on 0 1733-243400, fax 01733243344 or HYPERLINK mailto:z.ure@epsltd.co.uk*