Implementation of HC Refrigerants in a Hospital Environment

The Aarhus University Hospital, Skejby, has been in operation for a number of years using HCFC-22 based systems. The capacity had become insufficient over the years, but the plants could not be expanded due to a freeze from year 2000 of new installations. New installations in this case also cover expansion of the existing system. At the time of decision, it had become clear that the Danish regulation would only become more difficult and taxing of green house gases was being discussed. Evaluating the political ambitions and the possibilities left, only few options open. The choice fell on chillers using R290 (propane) and heat pumps using R600a (iso-buthane). Other options like CO\textsubscript{2} had also been evaluated but were found to be less efficient in the applications and the temperatures required.

- Alexander Cohr Pachai
A successful implementation of HC refrigerants in a hospital environment

A successful implementation of HC refrigerants in a hospital environment. However, due to obvious but, not very used most the heating system, which is very combining the cooling system with existing R-22 plants needed aUniversitets Hospital, Skejby. The possibility of making large systems with an HFC charge have later been introduced first in Denmark starting from January 1st 2007. This effectively eliminated the amount of R-22 that was reclaimed and taken out of service was about 2000 kg. The new system also offered a better performance meaning energy savings, which at the same time happens to save a lot of CO₂ emissions.

The first HC chillers were installed in 2003 and step-by-step and as the hospital has been expanded new HC chillers have been installed. The latest installation was two heat pumps with a total heating capacity of about 450 kW and a cooling capacity of about 325 kW. The units are build as two independent circuits so, it is basically two heat pumps on one frame. The two heat pumps are based on iso-buthane (R-600a).

The larger chiller system uses 9 air-cooled propane (R-290) based chillers each with a cooling capacity of 250 kW and a free-cooler with a capacity of 300 kW. The chillers have to deliver a 35% propylene glycol/ water solution at 9°C and return at 15°C.

<table>
<thead>
<tr>
<th>Winter load kW</th>
<th>Summer Load kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>200-300</td>
</tr>
<tr>
<td>Heating</td>
<td>400-500</td>
</tr>
</tbody>
</table>

Normally, the heating is provided by the district heating grid. The project included some talking with the local district heating company because the hospital normally is obliged to take the required heat from the grid. In the winter period, the supply temperature of water is 80°C and in the summer it is supplied at 70°C. The return is 40°C. This requires the heat pumps to deliver water at 80°C and at the same time cool water.

In the summer period, there is a base load for heating of tap water and room heating 400 to 500 kW which will be provided by the heat pumps. During the winter, there is also a cooling load which the heat pumps will be able in part to deliver while the rest will be managed by the free coolers.

Originally, the plan was to use heat pumps for the job. Investigations however turned out in favour of R600a. CO₂ may be of interest if you need really hot water about 85 to 90°C but at the actual temperatures R600a is more efficient.

Flammability issues

R600a and R290 are classified as A3 substances which indicate that they are flammable but not toxic. The standards require specially skilled persons to work with any refrigerant but in the case of hydro carbons, the number of skilled service technicians is a bit under what is required. Depending on the way the construction is done, you have to eliminate as many risks by design as possible. The topics that cannot be eliminated by design will need to be dealt within writing.

Using hermetic design with no shaft seals or semi-welded heat exchangers, most concerns are eliminated. If then, the unit is installed outdoor with a secondary loop including an efficient micro bubble separator, no gas will ever reach inside and the possibility of getting a flammable concentration is not present. When the systems are installed outdoor, you also have to make sure that the possibilities for building-up flammable concentration is eliminated effectively. The units do not ever operate in an explosive atmosphere. If a leak is detected, all power to the unit is cut out and can only be restarted manually from the panel. Remote reset is not possible because you have to verify what is wrong and what cut out the unit.

Very often, the flammability limits...
The important lesson learned was that insulation needs more considerations than normally compared to the refrigeration systems. In a normal refrigeration system, you have to keep the liquid temperature as low as possible and any heat rejected from the discharge pipe and from the liquid line is welcome. In the heat pump, you have to consider this as a loss. Also the insulation material used needs some careful selection. Normal cell rubber or foam can normally not be used at the high temperatures. You have to look at mineral wool or other sorts of wool insulation. Typically, the thickness will also increase but the good side is that, it normally does not increase the price because we are here working with high volume products from other parts of business. The heat loss can be quite substantial and we have estimated it to be about 15 to 20%.

The University Hospital of Aarhus has another benefit from installing the heat pumps and that is supply insurance. The whole system is connected to a local generator set which ensure stable supply and independence of the local grid in case of a power blackout. Also the wish to make some energy savings has been a driver. The energy savings have mainly been realised from running the system on a big scale energy efficient plant rather than many smaller plants. Also, the water flow has now been upgraded and it is now monitored so, it can constantly be optimised.

On top of the energy savings has to be added the savings in CO₂ emissions. The heat pumps makes it possible to upgrade low value heat to high value heat in a very energy efficient way compared to the traditional boiler technology. The new plants performing better than the old R22 plants.

Some of the old chillers had been in operation about 20 years and the efficiency was not impressing anymore.

### Refrigerants

<table>
<thead>
<tr>
<th></th>
<th>R600a</th>
<th>R290</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower flammability limit LFL</td>
<td>1.8%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Upper flammability limit UFL</td>
<td>8.4%</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

The problem is probably that most people have an experience with city gas, which is a very different sort of fish when it comes to ignition.

Other gases have a very different flammability range & other properties and they are all in common use just for other purposes. Most other gases are used where you wish them to burn. In a refrigeration plant, we try to keep the gas inside because when it comes out, it has no value to the process any longer and has to be ventilated away.

### The experience

The heat pumps were put into operation in November 2010 and they have at the time of writing not been in operation, a full heating season yet. However, the experience with the heat pumps so far has been very good and they have met and even exceeded the expectations. This is partly because the running conditions were a bit different in the real world even though a lot of thoughts had been put into the design criteria.

The primary function of the heat pumps is to deliver cold water. The engaged capacity is therefore given by the cooling requirement. On the warm side, the flow is controlled to keep up the condensing temperature and the pressure in the local district heating system.

### Conclusion

The project has been a success and the University Hospital has got a new refrigeration system that complies with the Danish regulations which ban the use of HFC charges over 10 kg. At the same time, the hospital has avoided the high cost of HFC. The efficiency has also been very good and exceeds expectations.

A number of R22 chillers have been taken out of service and 2000 kg R22 has been recycled. The new chillers have about 210 kg R-290 in total and the heat pumps have 80 kg R-600a. On top of the 9 chillers there are also some special chillers around on the site working at different temperature levels. In total, there are HC 15 chillers on the site where the first were installed in 2003.

---

**Alexander Cohr Pachai** is employed in Johnson Controls Denmark. His main working area has been natural refrigerants. He sold, designed, installed, commissioned and trained staff in working with the first CO₂ supermarket sold on full commercial conditions in Denmark in 2001. In 2005-2006, the first supermarket in New Zealand was sold and commissioned also using HC and CO₂ as the cascade pair. In 2006 & 2007, the Shrewsbury plant was sold and commissioned using HC and CO₂ as the cascade pair. Along with these activities, Pachai has also been selling or assisting sales of a number of industrial installations including training of both engineers and service technicians. There has also been time for development of different types of systems and cycles based on CO₂ as working fluid.