RESEARCH & DEVELOPMENT

Ammonium Hydroxide in Ice Rinks

The Ince Rink in Nittorp.

Rebuilding of The Ice Rink in Nittorp, Sweden has proved a solution of ammonia in water to be an excellent brine, which can be used to at least -50°C. As the ammonia is already bound to water it has the good thermal properties of water and ammonia – the two best heat transfer compounds, which exist, without the negative properties of pure ammonia.

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The skating and ice hockey club in the small village of Nittorp, about 100 km east of Gothenburg, Sweden, faced a problem with its ice rink.

The rink was some 30 years old and designed to operate with dry expansion of ammonia in the rink tubes. 1985 it was changed to an indirect system with calcium chloride brine.

Unfortunately, the piping in the rink – ½" straight carbon steel tubes – turned out to be too small. The brine flow was too low to allow an even cooling of the rink, not sufficient freezing capacity at the end of the straight end-to-end tubes. A flow reversal system was thus installed with two sets of pumps, one for each direction. About every hour the flow was reversed.

In 2007 the evaporator corroded and had to be replaced. However, the practically only possible material of the heating surface – titanium – had a very long delivery time and is expensive.

The management thus decided to have look at other possible solutions, among others a change of the brine.

Some possible candidates were: *(table 1)*

Ethylene glycol. It is an excellent brine in the respect that it has a very large temperature range, a 30% solution can be used from -15°C to well over 100°C, but the thermal properties are worse than calcium chloride and the viscosity is higher.

Carbon dioxide. Probably the best heat transfer fluid in this temperature range but it is not very suitable for a small ice rink, which is not in operation for long periods.

At 25°C the pressure is 6 bar, far too high for the components in the cooling system.

Either an emergency cooling system has to be installed that operates at shutdowns, either accidental or on purpose, or the carbon dioxide is let to evaporate and disappear and the system is then refilled with carbon dioxide at the next start up.

Potassium formiate. Excellent thermal and hydraulic properties but corrosive (mild steel, zinc) and it also seem to leak more than normal (pumps, valves and fittings).

Methanol-Water. Good thermal properties but flammable. In some countries, just the mention of the word alcohol means that it could be stolen and used as a drink.

Ammonium hydroxide. It is the solution of ammonia in water. The term ammonium hydroxide is actually not correct as such a compound cannot be isolated, but it is generally used by scientists and engineers as alternative terms are too clumsy. It has excellent thermal and hydraulic properties but it has not been used before in Sweden, neither in ice rinks nor elsewhere.

The use of ammonium hydroxide

The investigation soon focused on ammonium hydroxide but there were some considerations:

- Thermal properties.
- Evaporation of ammonia.
- Corrosion & fouling.
- Previous experiences.
- Legal and environmental.
- The use in public spaces.

Would the advantages outrun possible risks? A study was made of the above considerations.

Thermal properties

Would ammonium hydroxide lead to a more even freezing without an unnecessary high power consumption?

A comparison between calcium chloride and ammonium hydroxide is seen in the table.

Striking is the high energy density – the product of the specific heat and the density - which is about 15% higher than for calcium chloride and the low viscosity. That means that a given pump will pump a larger volume of ammonium hydroxide with a higher energy density than calcium chloride, i.e. the temperature drop along the rink tubes is less. The thermal conductivity is less than calcium chloride but that is not too important as the thermal resistance mainly occurs in the concrete, in which the tubes are embedded.

The conclusion was that ammonium hydroxide would improve the freezing of the rink.

Evaporation of ammonia

- Ammonium hydroxide is volatile and it was of some concern that ammonia would evaporate and thus increase the freezing point. As seen from the table, 17.7% ammonium hydroxide has a bubble point of more than 52°C and a freezing point of -30°C, considerably lower than necessary in an ice rink. Presumed that the ammonium hydroxide is kept in a closed circuit, there will be no evaporation of ammonia.

Tabel 1:

NH_4OH								$CaCl_2$-H_2O						
Freeze-point	NH_3 conc.	Bubble-point	Data at	Fp +10 K Cp	*cP			$CaCl_2$ conc.	Bubble-point	Data at	Fp +10 K Cp	*cP		
Fp°C	%	°C	kg/m³	kJ/kg,K	kJ/kg,K	W/m, K	cP	%	°C	kg/m³	kJ/kg,K	kJ/kg,K	W/m, K	cP
-50	23.6	39.7	937	4.37	4095	0.343	25							
-40	21.1	45.1	939	4.29	4028	0.389	7.1	28.3	>100	1284	2.685	3448	0.493	15.3
-30	17.7	52.3	944	4.265	4026	0.421	4.2	25.4	>100	1248	2.79	3482	0.511	8.1
-20	13.4	61.9	954	4.24	4045	0.459	2.75	21.0	>100	1199	2.985	3579	0.529	4.5
-10	7.8	75.6	971	4.218	4096	0.511	1.86	14.2	>100	1128	3.33	3756	0.552	2.5
0	0	100	1000	4.194	4193	0.577	1.3	0	100	1000	4.194	4193	0.5767	1.3
0	0	100	1000	4.194	4193	0.577	1.296	0	100	1000	4.194	4193	0.5767	1.3

Properties of Ammonium Hydroxide (NH_4OH) and calcium chloride ($CaCl_2$).