- The air above an ammonia solution contains very little ammonia. For a solution with the freezing point -15°C, the concentration is about 1600 ppm.
  In case of a leakage, dangerous concentrations can only arise in the immediate vicinity and only in an enclosed space.
- The concentration is far away from the combustion interval of ammonia, which is 15% to 28% in the air.

Corrosion & fouling

- All copper containing components have to be changed.
- Carbon steel is resistant up to a concentration of 15%, at higher concentrations stainless steel should be used.
- To check if the inevitable rests of calcium chloride could pose any risks, a simple test was devised. Some steel nails were put in a beaker with a test solution. Discolouring of the nails and the liquid reveals corrosion products.
  Test solution: 5% NaC_l
  Result: Traces of rust on the nails and a brownish colour of the liquid after two hours.
  Test solution: 5% NaC_l + 15% NH_3
  Result: No discolouring after one week.
  Thus, the conclusion was that the rinsing should be carefully done but the unavoidable traces of chlorides should not pose any problems.
- Ammonium hydroxide is a good cleaning solution, thus the heating surfaces are kept clean.
- There will be no problems with scaling and crystallization as could happen with calcium chloride, if the temperature drops below 0°C.

Previous experience

The only country where ammonium hydroxide brine is used to some extent seems to be France. However, no extensive investigation has been done.

The French installations have all been green field installations. Reports[1] have shown positive experience on the pumping cost and the general freezing behaviour.

The ice rink in Tours – also a green field installation – was converted to ammonium hydroxide a couple of years ago.

An interesting observation was made here. A leakage at the ice surface was not discovered for over a year. A calcium chloride leak would have destroyed the ice. No smell was noticed or did not cause any concern.

No negative experiences have been found but the investigation has not been extensive.

Legal and environmental

- In Sweden, the use of ammonium hydroxide with less than 25% ammonia has to be reported but permit or authorization is not necessary. Thus, practically all applications of are covered as this concentration can be used to a temperature well below -50°C.
- Ammonium hydroxide is poisonous to marine organisms and can thus not be disposed of by simply flushing it out with the waste water.
  Note, as the natural background concentration of ammonia is some 30 mg/l, in a larger body of water the danger of an ammonia leakage disappears rapidly.
- As the ammonia is already bound to water many of the possible dangers of pure ammonia are absent or vastly reduced.
- The environmental aspects of ammonia were not considered, they have been reported elsewhere[2].

Ammonia hydroxide in public spaces

As ammonium hydroxide has never before been used in an ice rink some considerations were made as to the safety of the system.

- **Machine room.** Pumps, expansion tanks, valves and evaporator are installed. The machine room is not a public space and it can be kept well ventilated.
- **The ice rink.** The pipes are embedded into concrete. The concrete and the pipes can obviously be damaged but the resulting leak – from one pipe out of some 300 – will be small and an ammonia vapour release will be close to the ice surface, where most is absorbed. See also the experience from Tours.
- **The duct machine room – rink.** This is a small enclosed space. A leak from e.g. a damaged flange could possibly lead to dangerous concentrations. However, this is no space where anybody should enter except for maintenance at a shut down plant.
  Note the difference to e.g. carbon dioxide or HCFs. Nobody would enter this space – e.g. to retrieve a lost object – if (s)he would meet an ammonia smell. In case of carbon dioxide that could happen with possible fatal consequences.
- **Conclusion.** The early warning signal of ammonia makes ammonium hydroxide brine very safe without the negative effects of pure ammonia.

Experience of the conversion

- A manometer with brass parts, which was not changed, was corroded.
- 30 years operation with ammonia and calcium chloride had thoroughly fouled the circuit. The ammonium hydroxide was black.
  Thus the first year could be considered as the „cleaning year". A filtration of the ammonia solution showed a sludge similar to the one found in CaCl2 for ice melting on roads. The fear that it should be corrosion products from iron was unfounded.
  A small by-pass was installed to make a continuous filtration.
- No measurements were made of the power consumption but the pumps were running at lower speed.
  The impression of the operators was that the ice formation responded much quicker than previously to changes in the brine temperature.
- This was confirmed, when one of the pumps failed, thus no flow reversion. It was not noticed for over a week, i.e. no major difference of the freezing behaviour between the inlet and exit of the tubes.
- No smell has been noticed.

Conclusion

Ammonium hydroxide is 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.

It might also help to increase the acceptance of the use of ammonia in public spaces.

It thus deserves a wider use, not only in ice rinks but also as a general, low temperature brine.

References

1 Ammonia Water Solution as Secondary Refrigerant, Advantages and Drawbacks. Valérie Gibert/Axima, France.
Presented at a conference in Ohrid, Macedonia, 2007.

2 E.g. Ammonia's Future as Refrigerant.
A. Lindborg/Ammonia Partnership.
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Pumps, expansion tanks, valves and evaporator are installed in the machinery room.