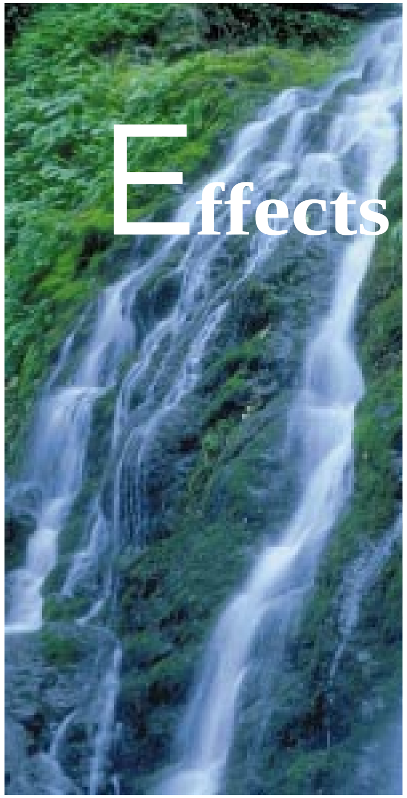
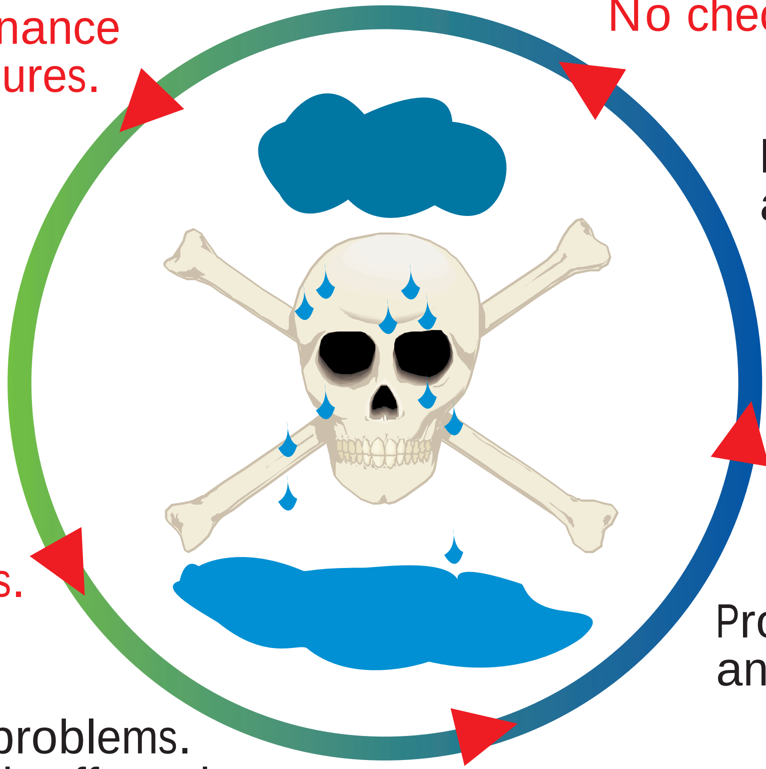


Effects of water contamination “The evil circle”



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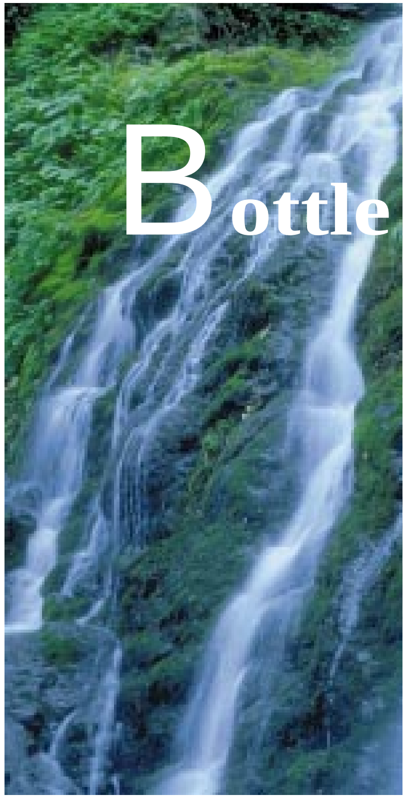
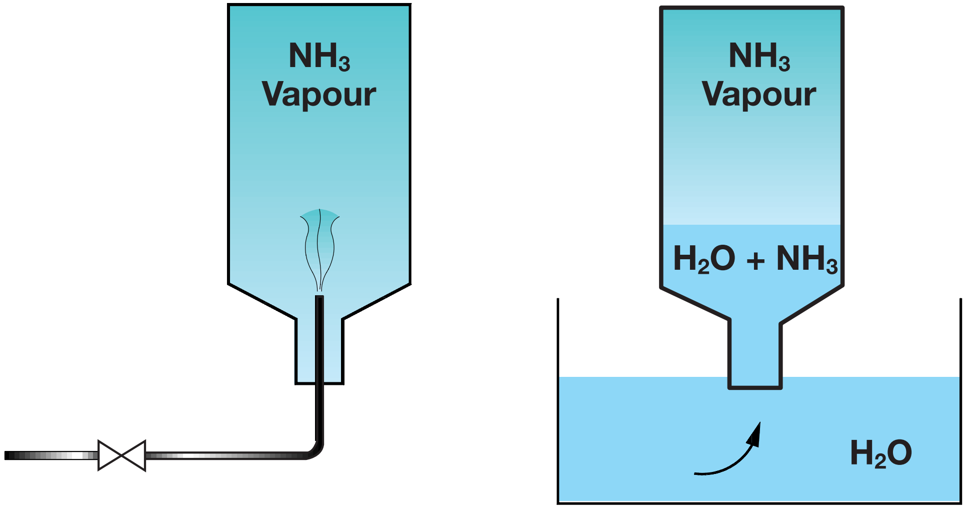
March 1998

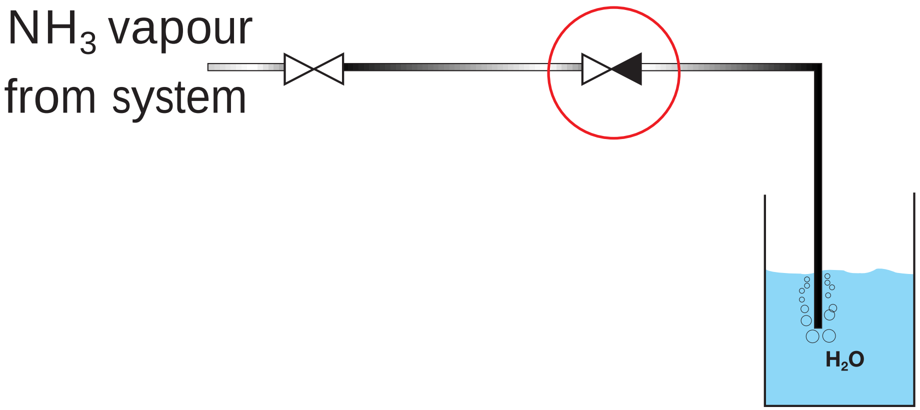


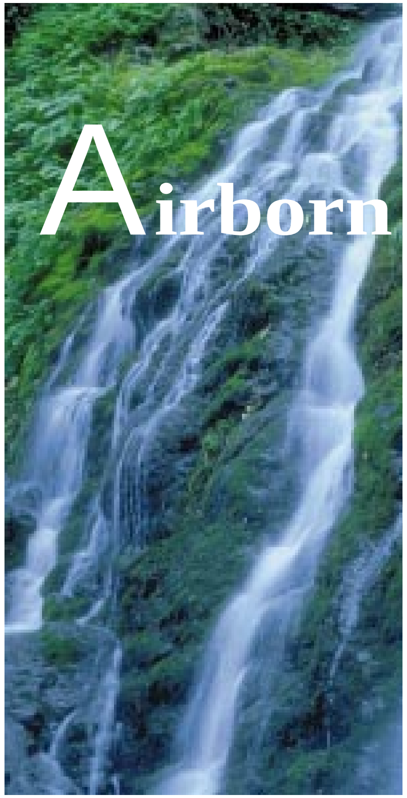
Bottle test

- shows the affinity between NH_3 and H_2O



Always use a checkvalve, when evacuating through water





Airborn moisture

Max. capacity for an airpurger is approx. 10 l/min. (at atm. press.)

Imagening "Worst Case":

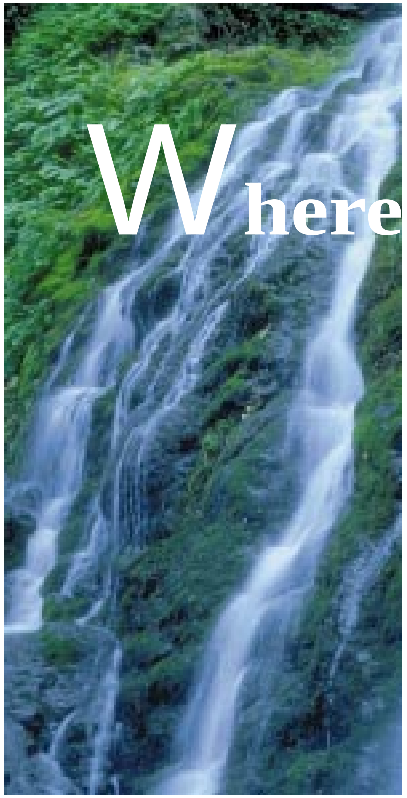
Purging 5 l/min. air continuesly.

Ambient temperature 20°C (43,1 F). Humidity 80%.

This means:

- 4.15 g H_2O enters the system each hour.
- 36.35 litres each year.
- 363.5 litres H_2O after 10 years.

After 10 years:
363.5 kg ≃ 6058 l NH_3 charge have 10% H_2O content.
181.8 kg ≃ 3029 l NH_3 charge have 20% H_2O content.



Where the water goes in the system depends on the design

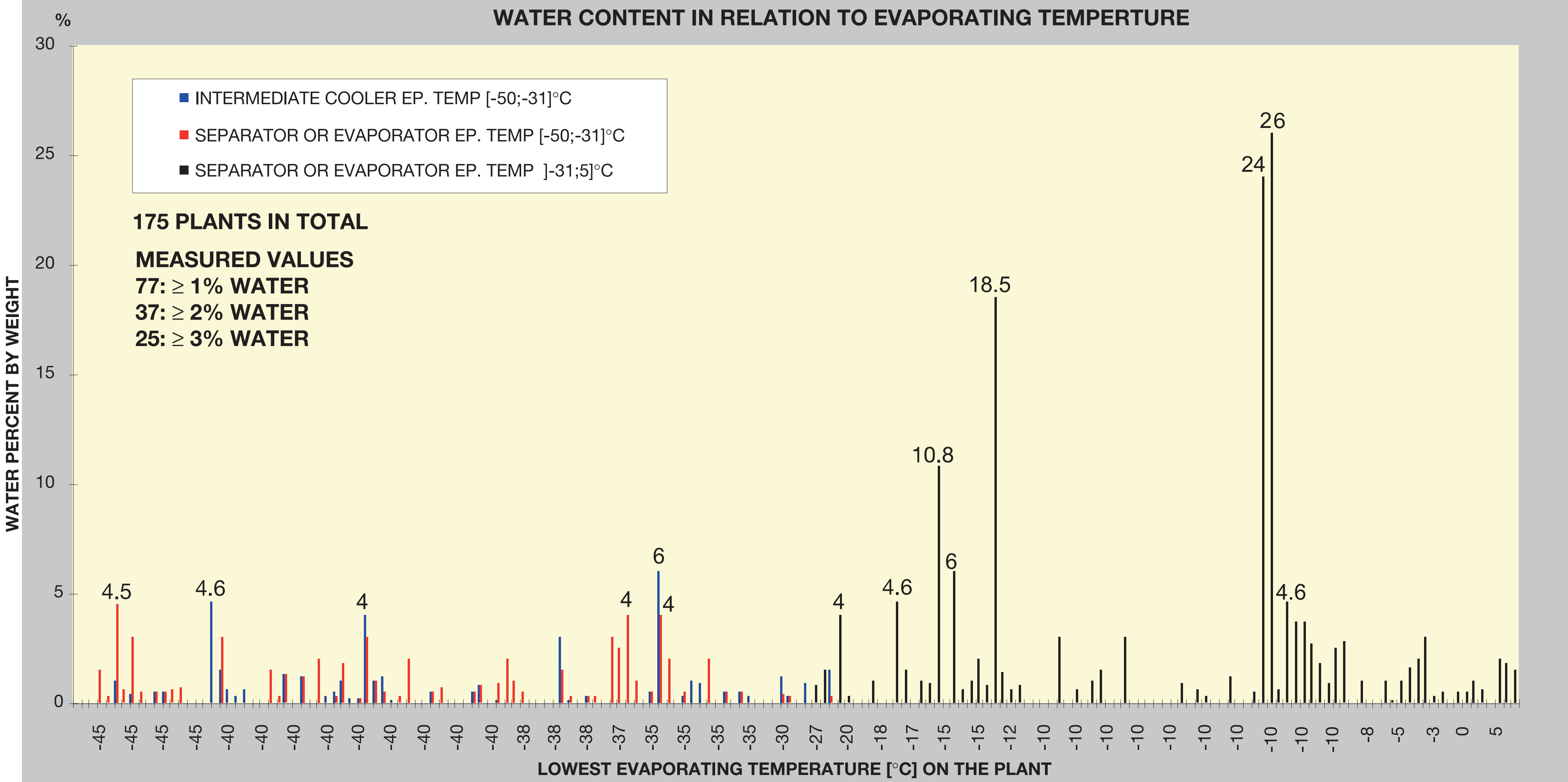
- **Flooded systems with efficient liquid seperators:**
  H_2O stays on LP side and EP side
  (separators/evaporators, intermediate coolers).
  Liquid carry over ⇒ high amounts of H_2O can go to compressors.

- **Systems where defrost drainlines goes to HP side:**
  H_2O will be carried to everywhere in the system.
  Dangerous for compressors with liquid injection, dry expansion economizers and intermediate cooling.

- **Dry expansion systems:**
  H_2O is carried with high velosity suction gas to the separator/compressor.

NOTE: Thermostatic expansion valves will react on the change in saturated temp. for $NH_3 + H_2O$ as “superheat” and might be unable to control the evaporator.

Water content in relation to evaporating temp.



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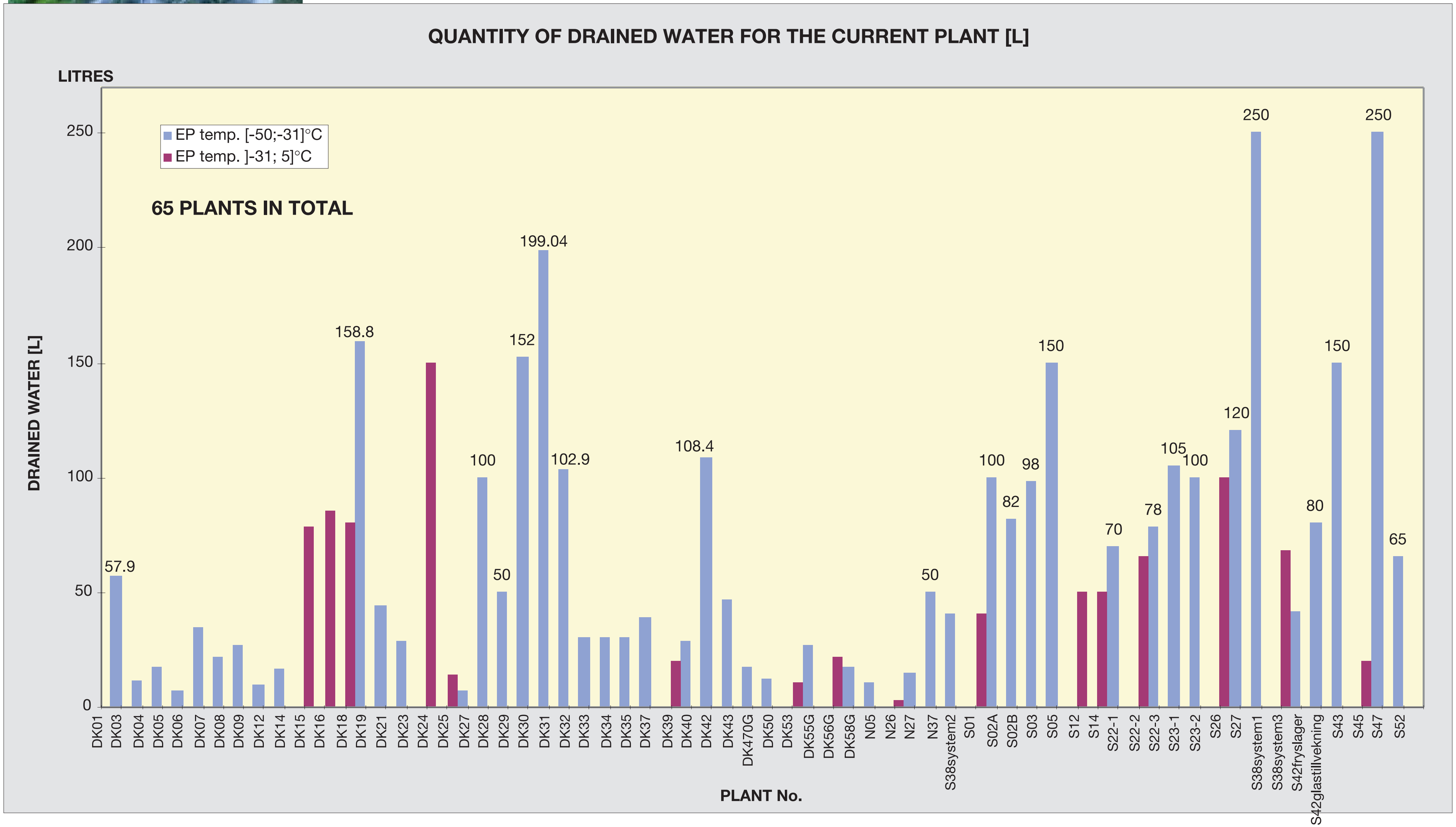
March 1998

Quantity of drained water for the current system [L]



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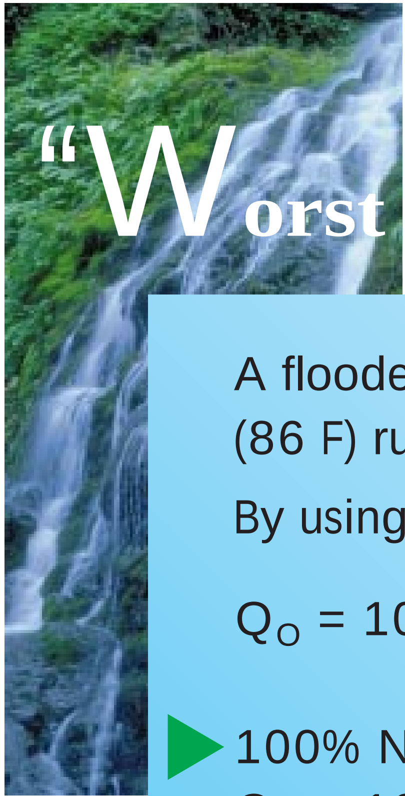
March 1998

Thermodynamic properties $NH_3 + H_2O$

Saturation pressure bar	Saturation temperature, °C if NH_3 70% H_2O 30%	80% 20%	90% 10%	100% 0%
0.05	NA	NA	NA	NA
0.1	NA	NA	NA	NA
0.2	NA	NA	NA	NA
0.3	-47.15	NA	NA	NA
0.4	-42.10	-46.48	-48.82	NA
0.5	-38.00	-42.51	-44.93	-46.52
1.0	-24.07	-28.96	-31.71	-33.59
2.0	-7.71	-13.63	-16.70	-18.85
3.0	2.51	-3.16	-6.69	-9.23
4.0	10.32	4.45	0.79	-1.88

Saturation temp. °C	Saturation pressure, bar if NH_3 70% H_2O 30%	80% 20%	90% 10%	100% 0%
-50	0.254	0.326	0.373	0.408
-48	0.285	0.366	0.420	0.459
-46	0.321	0.411	0.471	0.515
-44	0.360	0.460	0.527	0.576
-42	0.402	0.514	0.588	0.644
-40	0.449	0.573	0.655	0.717
-38	0.500	0.637	0.728	0.797
-36	0.556	0.708	0.808	0.885
-34	0.617	0.784	0.895	0.980
-32	0.679	0.861	0.986	1.08



"Worst case" calculation example

A flooded system with screw compressors at ET = -42°C (-43.6 F) , CT = 30°C (86 F) runs 10 hours/day 300 days a year.

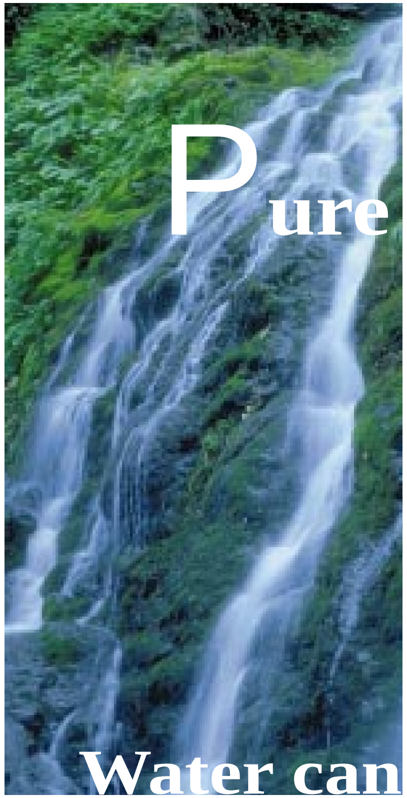
By using COP = $\frac{Q_O}{N_E}$, what is the power consumption (N_E) each

Q_O = 1000 kW (284 TR)/year

- 100% NH_3: EP = 0.64 bar a (9.28 psia) Q_O = 361.7 kW (102.7 TR)
  Q_O = 1000 kW (284 TR) ⇒ N_E = 2097900 kWh/year.

- 90% NH_3 + 10% H_2O: EP = 0.59 bar a (8.56 psia) Q_O = 327.1 kW (92.9 TR)
  Q_O = 1000 kW (284 TR) ⇒ N_E 2272800 kW/year ⇒
  additional N_E = 174900 kWh/year each Q_O = 1000 kW.

- 80% NH_3 + 20% H_2O: EP = 0.51 bar a (7.40 psia) Q_O = 278.8 kW (79.2 TR)
  Q_O = 1000 kW (284 TR) ⇒ N_E = 2586300 kWh/year ⇒
  additional N_E = 488400 kWh/year each Q_O = 1000 kW (284 TR)



Pure anhydrous ammonia is not very chemical reactive

- *"Wet" ammonia form the very chemical reactive:*

ammonia + water $\Leftrightarrow$ ammoniumionhydroxyd

$NH_3 + H_2O \Leftrightarrow [NH_4 + OH]$

corrosive (can lead to galvanic corrosion)

Water can be created in the system

- *Reaction with acid from oxydation of oil.*

Ammonia + acid $\Leftrightarrow$ Ammonium carboxylat $\Leftrightarrow$ amide + water

$NH_3 + RCOOH \Leftrightarrow RCOONH_4 \Leftrightarrow RCONH_2 + H_2O$

sludges free water

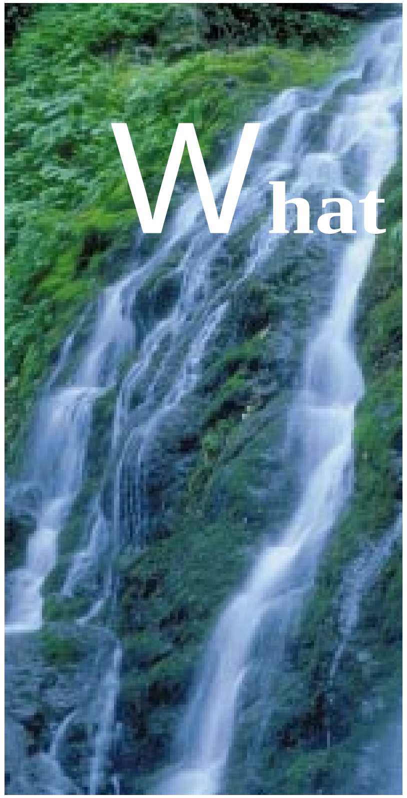
- *Air in the system will allow following reaction:*

Ammonia + carbon dioxyde $\rightarrow$ ammoniumcarbamate $\rightarrow$ carbamide + water

$2NH_3 + CO_2 \rightarrow H_2NCOONH_4 \rightarrow H_2NCONH_2 + H_2O$

from air; very corrosive to steel; sludge; free water

Per Skærbæk-Nielsen, M.Sc. Mech.
March 1998

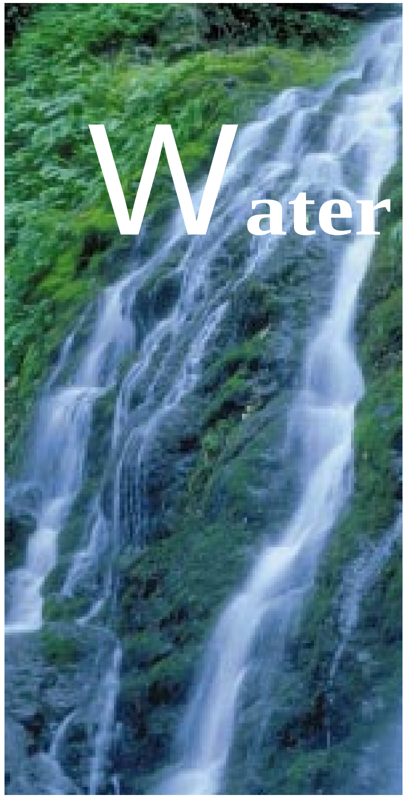


What happens to the oil?

Oxydation: Oil + oxygen + water ⇒ precursors + organic acids.
Nitriding: Oil + ammonia+ water ⇒ precursors + organic acids

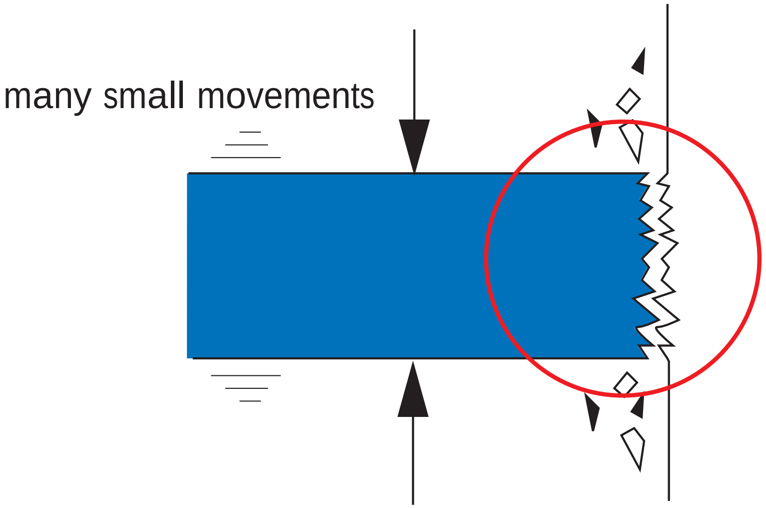
Organic acid + ammonia ⇒ nitro compounds
(sludges, salts, soap products).

Nitro compounds:
- are partly soluble in ammonia.
- are not soluble in oil.
- can escape through oilseperators.
- makes sludges in the compressors and in the system (valves, controls, evaporators etc.).
- acts as catalysist and are amplifying the process of creating more nitro compounds.



Water related problems on valves and controls

- **Rust and sludges:** Valves, filters can get “clogged” or stock.
- **Fretting corrosion:** Vibrations / pulsations ⇒
  fattigue in asperities ⇒
  asperities brake off ⇒
  free particles on surfaces + corrosion ⇒
  particles “grow” in size ⇒
  increased friction ⇒
  more wear ⇒
  valves / controls can get “stock”



$2Fe + O_2 \rightarrow 2\,FeO$	black.
$3FeO + {}^1/_2O_2 \rightarrow Fe_3O_4$	blue / black
$2FeO_4 + {}^1/_2O_2 \rightarrow 3Fe_2O_3$	red / brown ⇒ “wear”.
$Fe_2O_3 + H_2O \rightarrow 2FeOOH$	red / brown “rust”.

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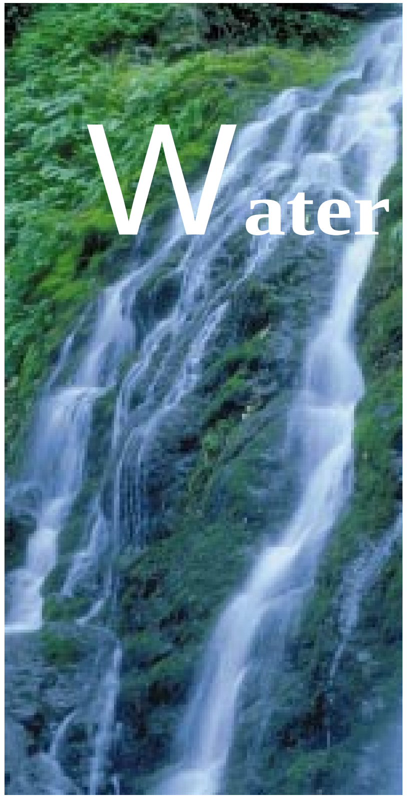
March 1998



Water related problems in expansion devices

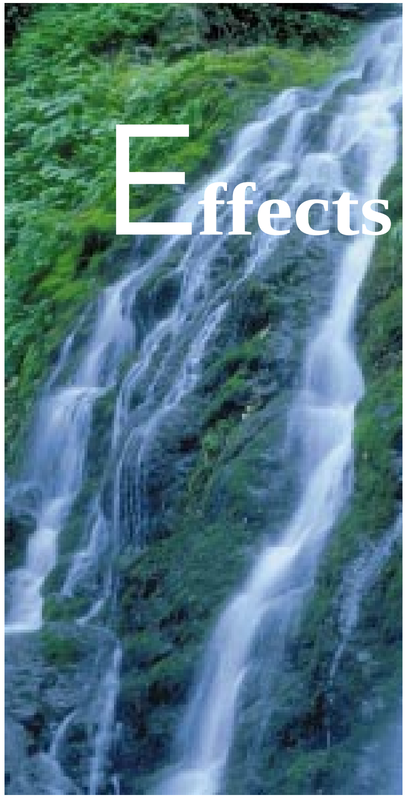
- Highly increased wear problems in expansion devices.

  Possible reasons (not proven):
  Increased errosion because of high amount of dirt particles.
  Collaps of water vapour into small drops with a cavitation effect.
  Introducing corrosion with the errosion and cavitation.

- Thermostatic expansion valves might not operate correctly due to changes in saturated liquid temp. for NH_3 + H_2O

Conclusions on water contamination

- NH_3 systems often contain more water than recommended.
- Proper procedures in service work plays an important role.
- Automatic airpurgers can “hide” leak problems.
- System design is important for water related problems.
- Water related problems are not very well-known to system operators and service staff.
- Detection of water contamination should be carried out as part of normal service and maintenance (IIar Bulletin No. 108).
- Installation of water rectifiers can prove to be a very attractive investment (IIar Bulletin No. 108).



Effects of keeping systems dry
"The good dry circle"

Curing the real problem not only the symptoms.

Checks for water. Use of water rectifiers (IIar Bulletin No. 108).

Decreased service and running costs.

Capacity and power consumption are not effected.

Less problem on valves and controls.

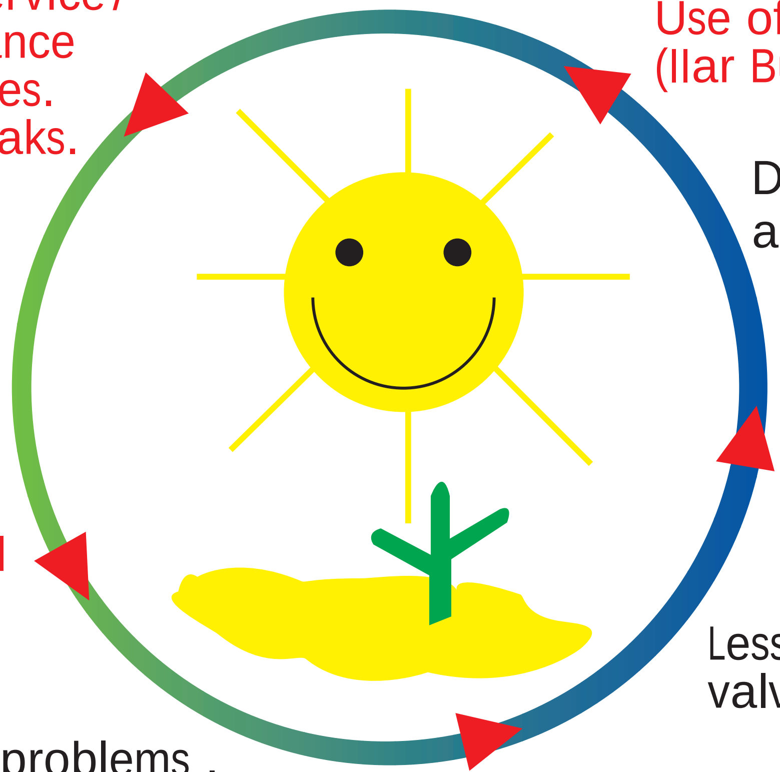
Minimum of possible corrosion.

Less oil and sludge problems . Longer service intervals.

Minimum of chemical reactions.

Minimum of H_2O enters.

Proper service / maintenance procedures. Repair leaks.



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