Ammonia Desorption in Microscale Fractal-Like Branching Flow Networks

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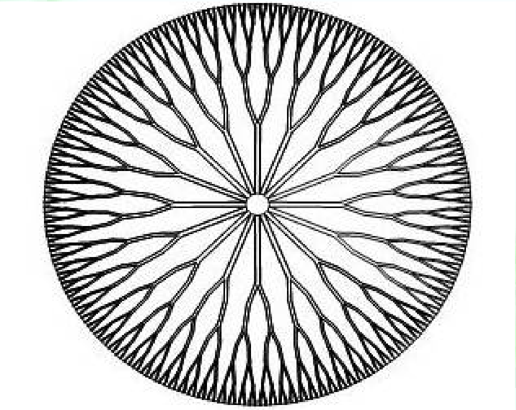
Introduction

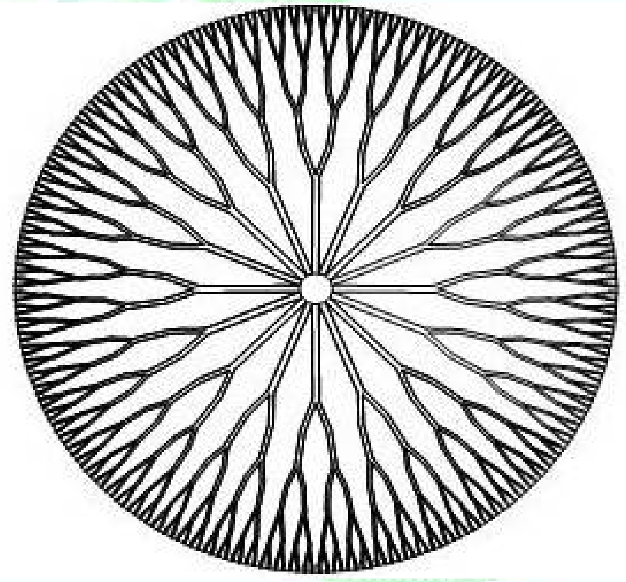
- **Macroscale desorption**
  - **Droplet**
  - **Thin film**
- **Microscale desorption**
  - **Enhanced heat transfer capabilities**
  - **Enhanced mass transfer capacity**

- **Parallel microchannel desorber**
  - **Large pressure drop**
  - **Potential for flow channel blockage**
- **Fractal-like microchannel desorber (based on natural flow networks - fixed diameter and length ratios)**
  - **Low pressure drop**
  - **Alternate flow paths**

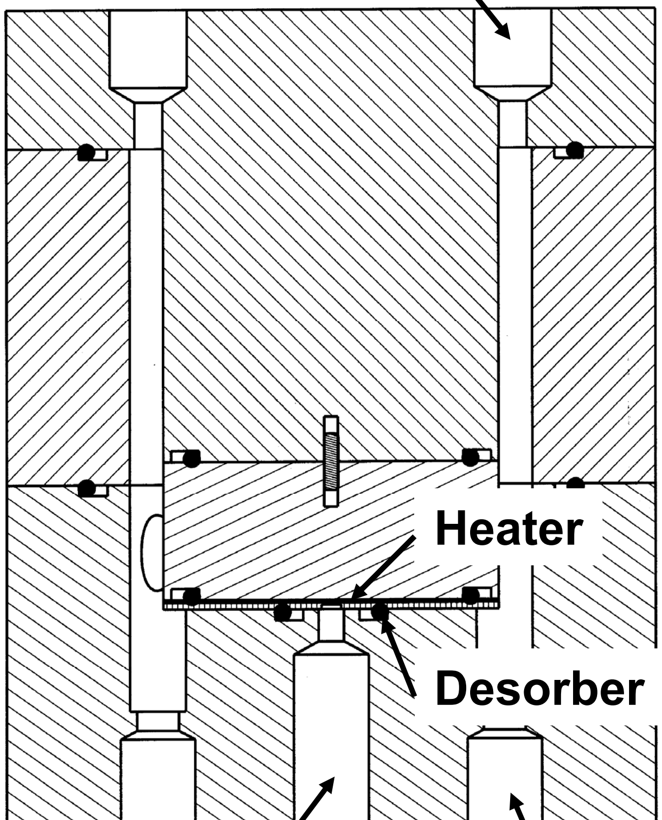


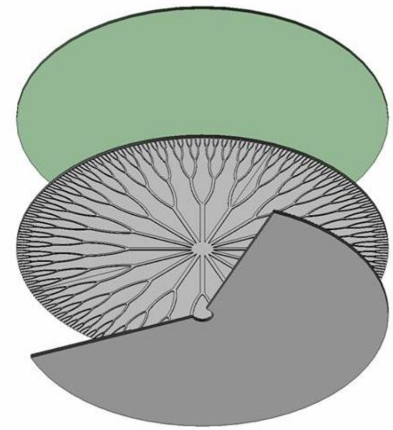
Objectives

- Assess feasibility of desorption using a fractal-like branching channel heat sink (ammmonia/water binary mixture)
- Quantify desorption rates and mass fraction as a function of
  - Applied heat flux
  - Flow rate

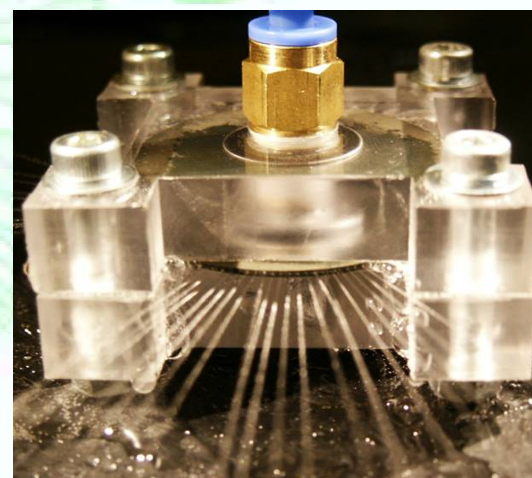


Test Device





Courtesy of Christoff Pluess



Courtesy of Christoff Pluess

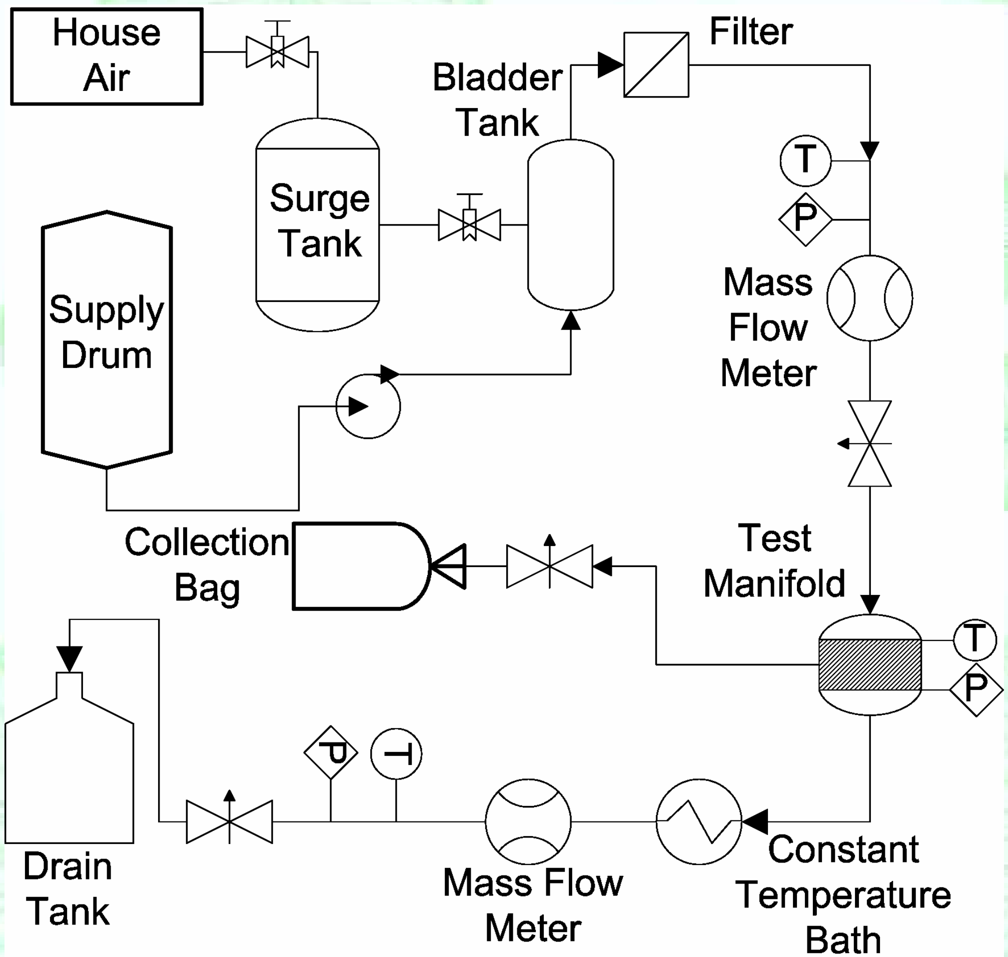
Dimensions of Flow Network

k	H_k (mm)	w_k (mm)	d_k (mm)	L_k (mm)
0	0.158	0.430	0.128	5.80
1	0.150	0.297	0.122	4.10
2	0.137	0.210	0.110	2.90
3	0.126	0.147	0.100	2.05
4	0.112	0.107	0.088	1.45

* k indicates branching level

* k = 0 emanates from inlet plenum

Flow Loop



House Air
Filter
Bladder Tank
Surge Tank
Supply Drum
T
P
Mass Flow Meter
Collection Bag
Test Manifold
T
P
Drain Tank
P
T
Mass Flow Meter
Constant Temperature Bath

Data Reduction

- Mass flow rate of vapor

$$\dot{m}_v = \dot{m}_{ss} - \dot{m}_{ws}$$

- Mass fraction of ammonia in liquid streams

$$x = f(T, P, \rho)$$

Ibrahim & Klein (1993)

- Mass fraction of ammonia in vapor stream

$$x_v = \frac{x_{ss}\dot{m}_{ss} - x_{ws}\dot{m}_{ws}}{\dot{m}_v}$$

Uncertainty

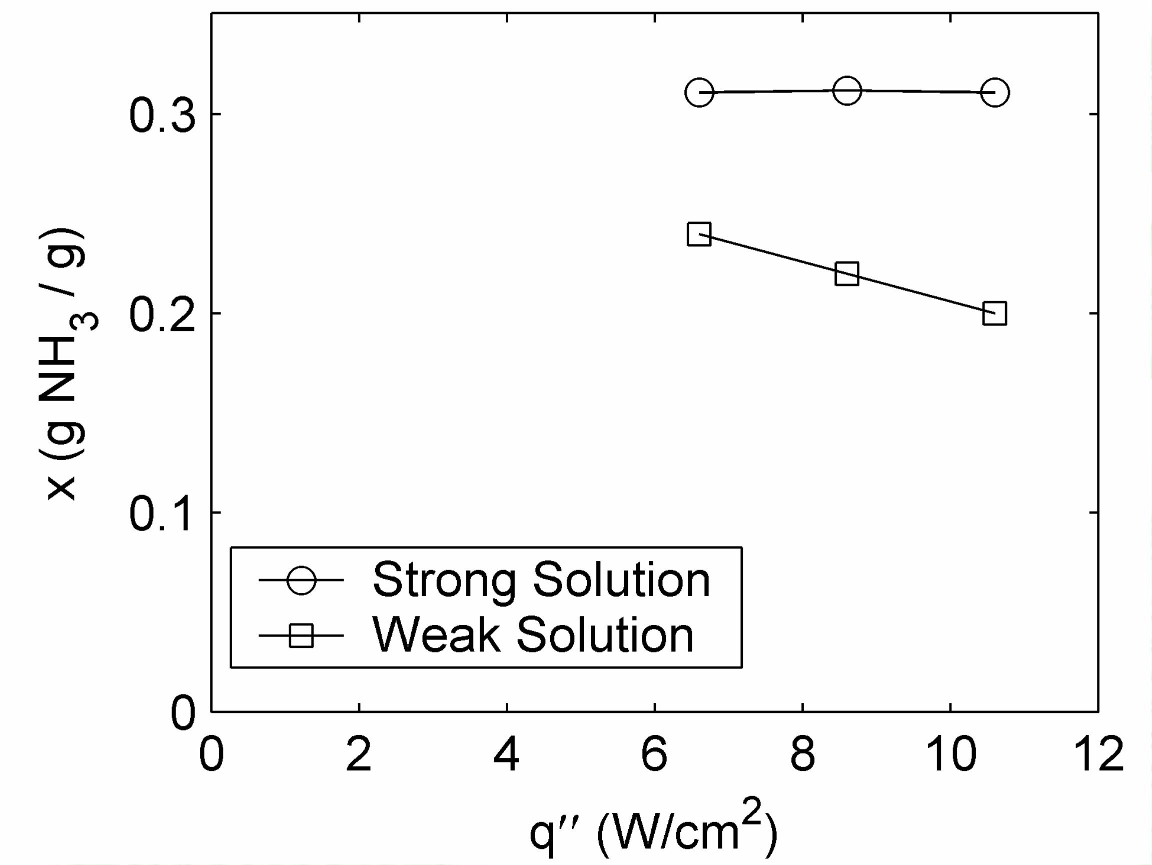
Measurement	Location	Operating Range	Uncertainty	Units
Flow Rate	Liquid	15-25	±0.05	g/min
	Vapor	1.5-3	±0.07	g/min
Mass Fraction	Liquid	0.2-0.3	±0.003	g_{NH3}/g
	Vapor	0.93-0.99	±0.15	g_{NH3}/g
Temperature	Thermocouple	37-47	±0.2	°C
	RTD	20-22	±0.09	°C
Pressure	Upstream	300 (typ)	±11	kPa
	Downstream	135 (typ)	±1.2	kPa
Density	All	890-925	±0.5	kg/m^3
Heat Flux	All	6-12.6	±0.05	W/cm^3

Test Matrix

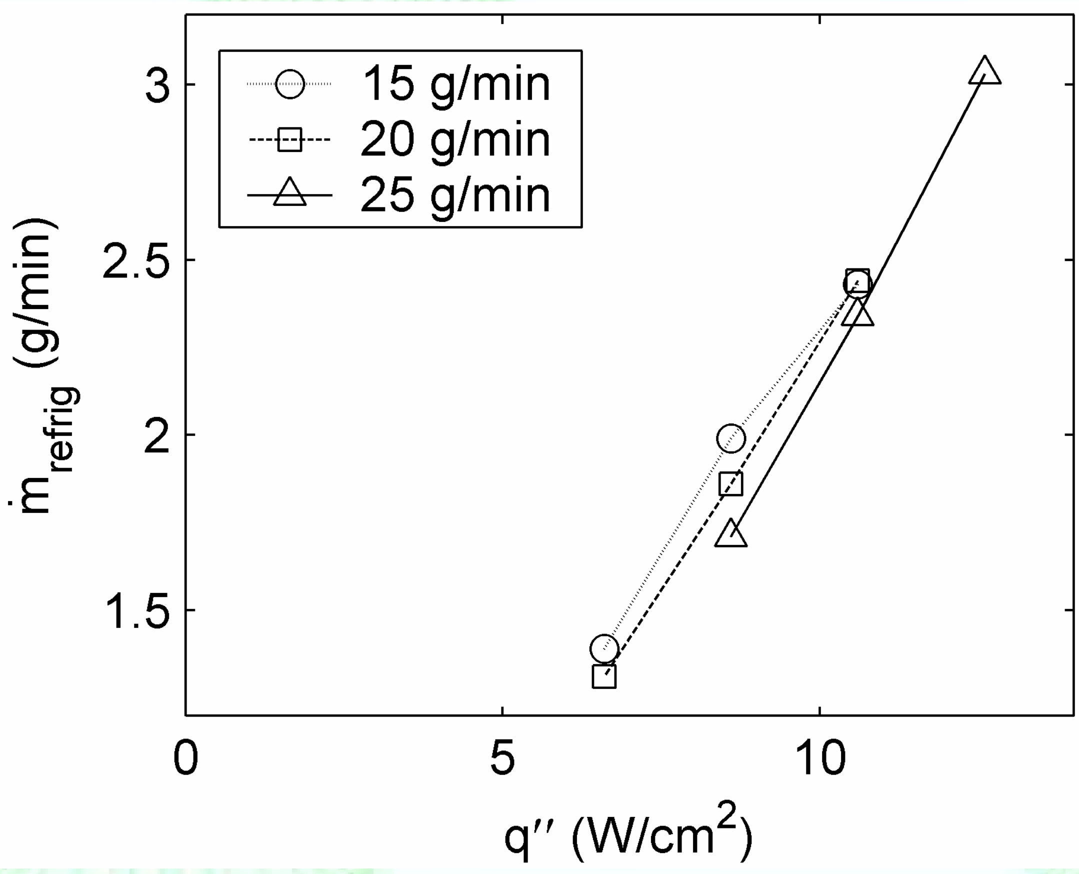
	15 g/min	20 g/min	25 g/min
6.6 W/cm^2	X	X	-
8.6 W/cm^2	X	X	X
10.6 W/cm^2	X	X	X
12.6 W/cm^2	-	-	X

Ammonia Mass Fraction versus Heat Flux

$$\dot{m}_{ss} = 15 \ \text{g/min}$$

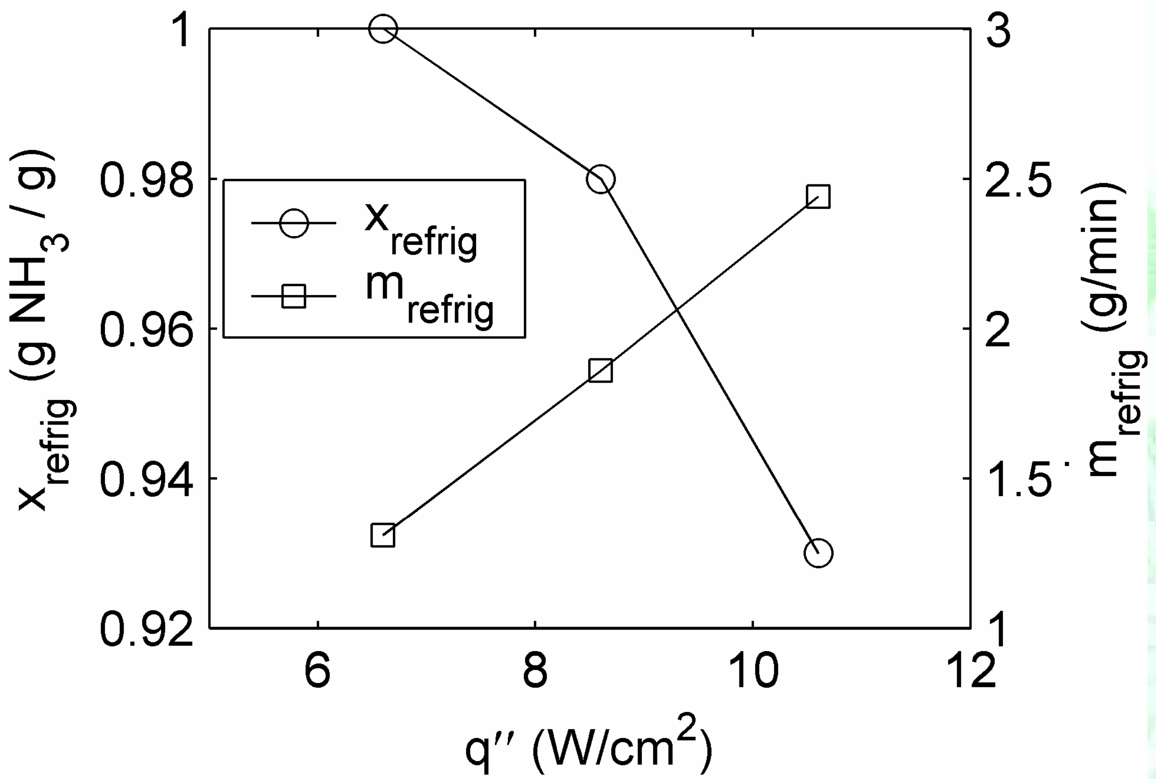


Mass Flow Rate of Vapor versus Heat Flux and Strong Solution Flow Rate



Mass Fraction and Vapor Flow Rate versus Heat Flux

$$\dot{m}_{ss} = 20 \ \ g/min$$



Conclusions

- Desorption of ammonia in fractal heat sink demonstrated
- Increases in heat flux yield
  - Increases in desorption rate (vapor flow rate)
  - Decreases in ammonia mass fraction in vapor
- Increases in strong solution flow rate yield
  - Decreases in desorption rate
  - Increases in ammonia mass fraction in vapor
- Competing effects of desorption rate and mass fraction require desorber design optimization based on cooling requirements

Acknowledgements

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