

# **EFFECTS OF OPERATION CONDITIONS ON INCRUSTATION PHENOMENA**

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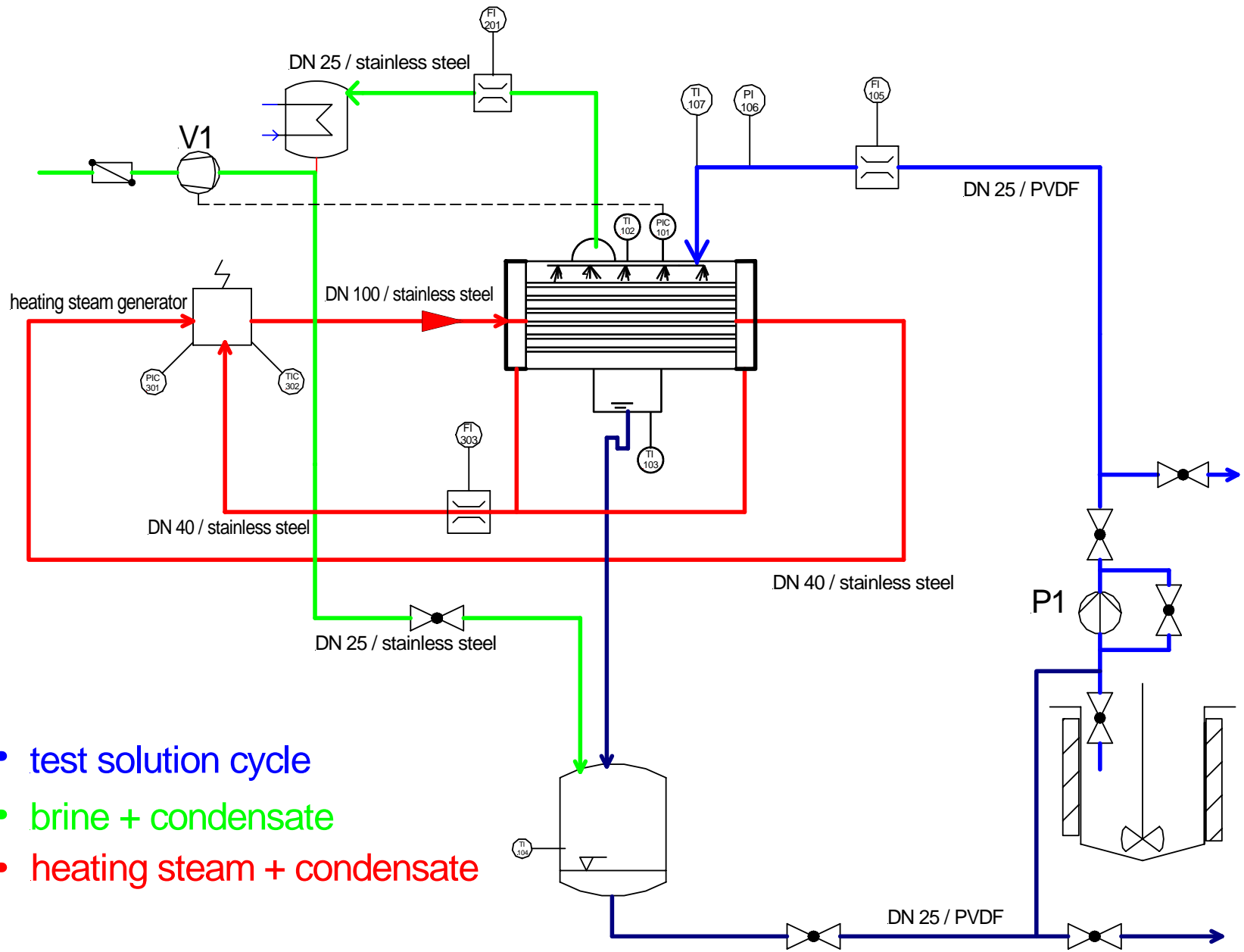
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# Introduction

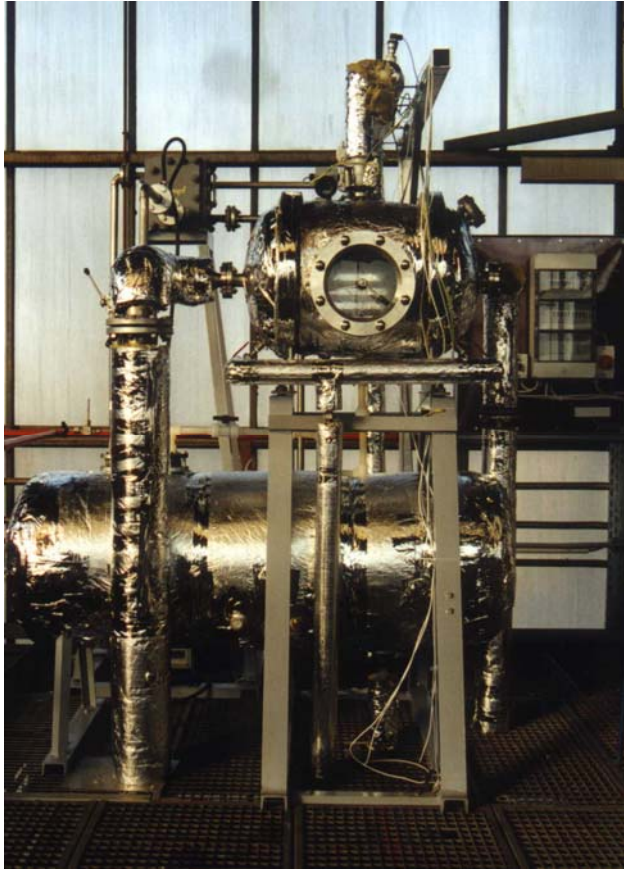
- Process:
- **Multi-effect distillation (MED) on horizontal tubes**
  - produces better water quality than membran processes
  - is more efficient than multi-stage flash (MSF)

- Problem:
- inversely soluble salts:  $\text{CaCO}_3$ ,  $\text{CaSO}_4$ ,  $\text{Mg}(\text{OH})_2$
  - scale forms outside of tubes
  - diminishes process efficiency
  - scale prevention and cleaning are difficult

- Aim:
- to create authentic scale layer to understand and to prevent incrustation process



- test solution cycle
- brine + condensate
- heating steam + condensate



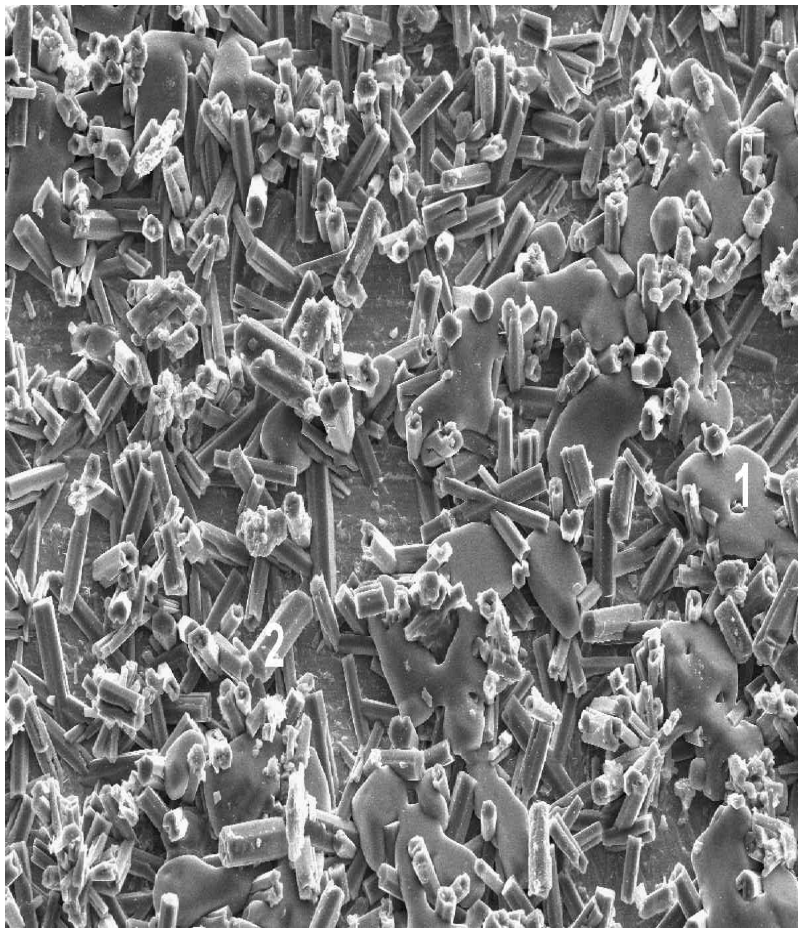
⇐ platform 2: horizontal tube evaporator



↑ platform 1: heating steam generator

# Seawater Solution

Salt	g/L
NaCl	23,926
Na <sub>2</sub> SO <sub>4</sub>	4,008
KCl	0,677
NaHCO <sub>3</sub>	0,196
KBr	0,098
H <sub>3</sub> BO <sub>3</sub>	0,026
NaF	0,003
MgCl <sub>2</sub> × 6H <sub>2</sub> O	10,83
CaCl <sub>2</sub> × 2H <sub>2</sub> O	2,75
SrCl <sub>2</sub> × 6H <sub>2</sub> O	0,013



1000 : 1

a)

20  $\mu\text{m}$



1000 : 1

b)

20  $\mu\text{m}$

Figure 1: SEM showing crystals formed at same heating and evaporation temperature with test solutions of a salinity difference of 10 g/kg.





1000 : 1

a)

20  $\mu\text{m}$



1000 : 1

b)

20  $\mu\text{m}$

Figure 2: SEM showing crystals formed at different heating and evaporation temperature levels with the same test solution.

# Heat Transfer Data

	$\Delta T = 10 \text{ K}$	$\Delta T = 20 \text{ K}$
$T_{\text{steam}} [^{\circ}\text{C}]$	80	90
$T_{\text{evap}} [^{\circ}\text{C}]$	70	70
$Q [\text{kW}]$	3.7	7
$k [\text{W}/\text{m}^2 \text{ K}]$	1000	1100

Heat transfer area :  $0.254 \text{ m}^2$

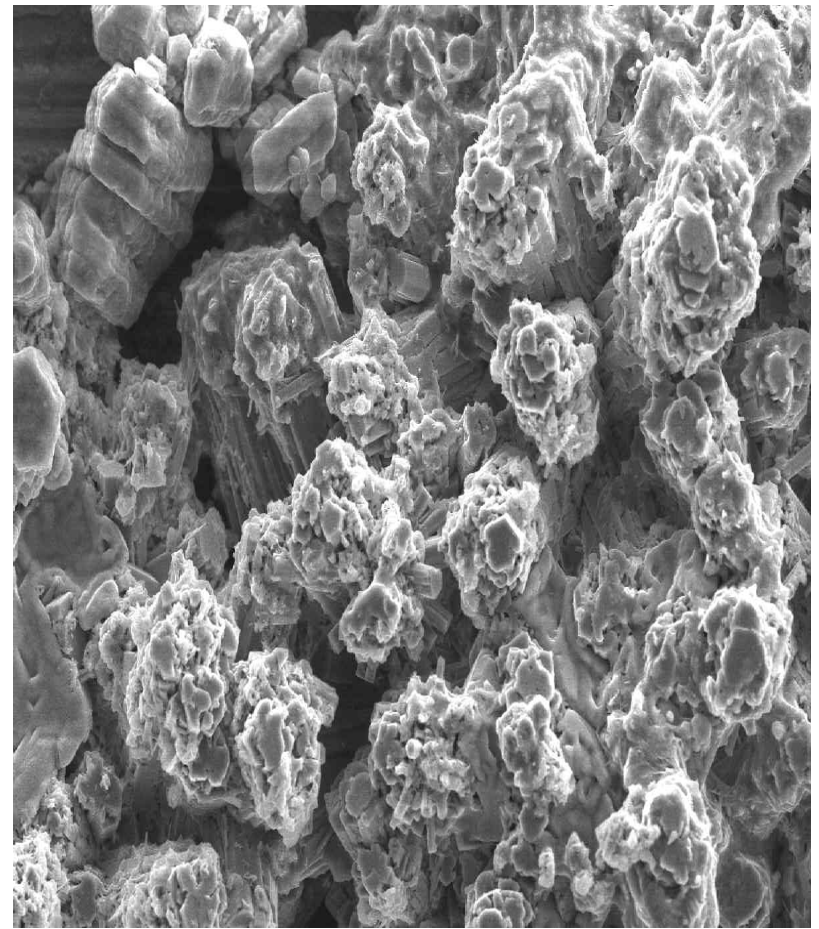




1000 : 1

a)

20 μm



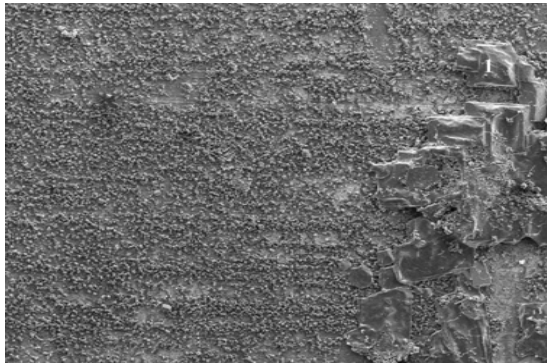
1000 : 1

b)

20 μm

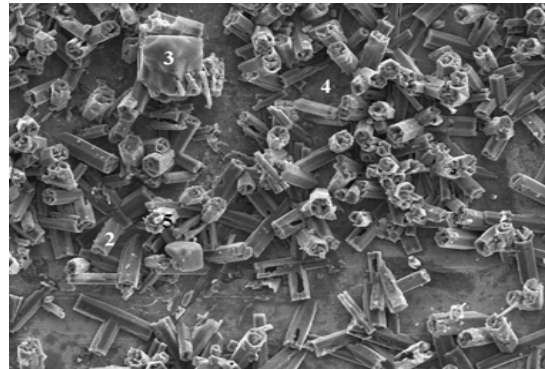
Figure 3: SEM showing crystals formed at different  $\Delta T$  between heating and evaporation with the same test solution.

# SEM Pictures of Crystal Layers



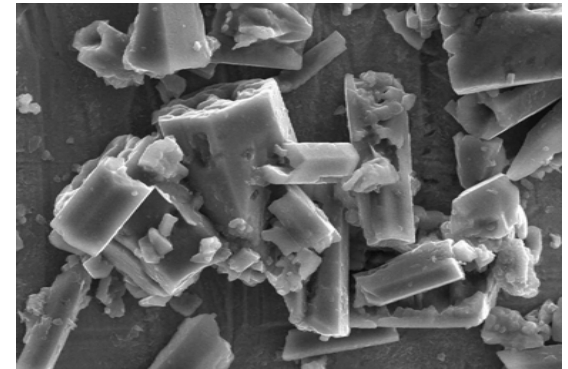
100 : 1

200 μm



1000 : 1

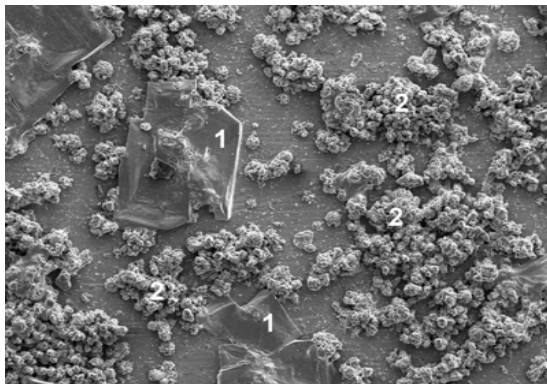
20 μm



5000 : 1

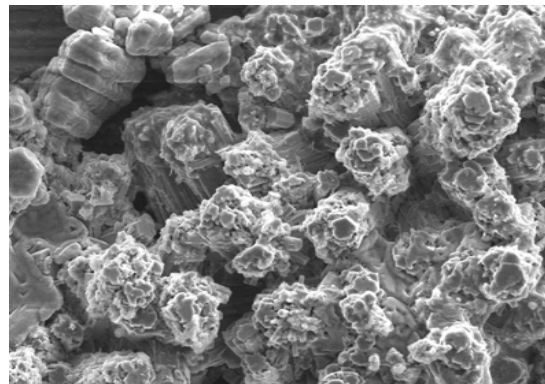
5 μm

crystal structure at  $\Delta T = 10$  K after 50 h



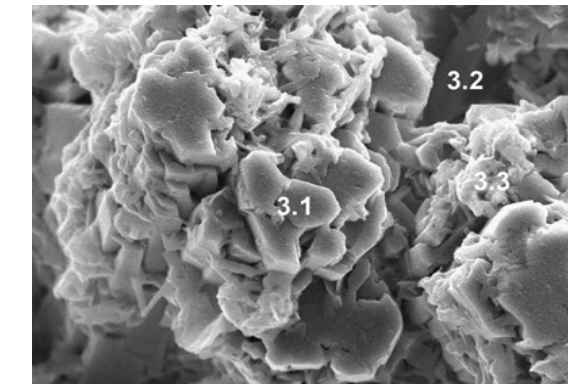
100 : 1

200 μm



1000 : 1

20 μm

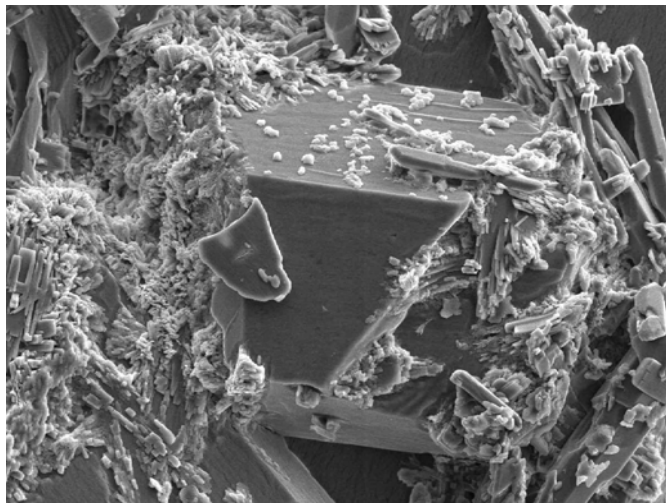


5000 : 1

5 μm

crystal structure at  $\Delta T = 20$  K after 50 h

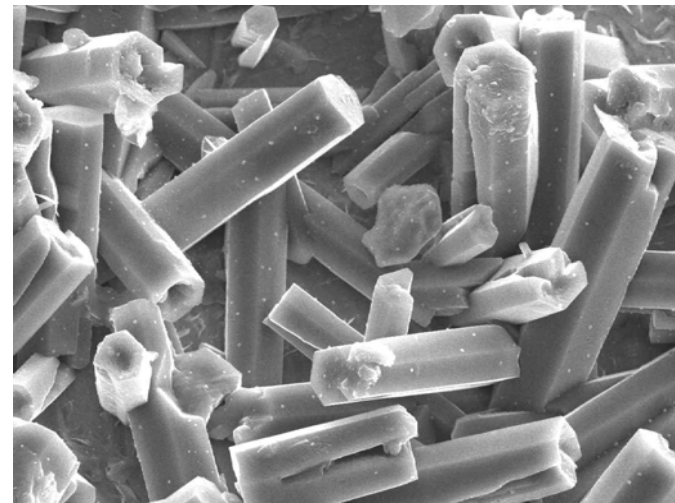




1000 : 1

a)

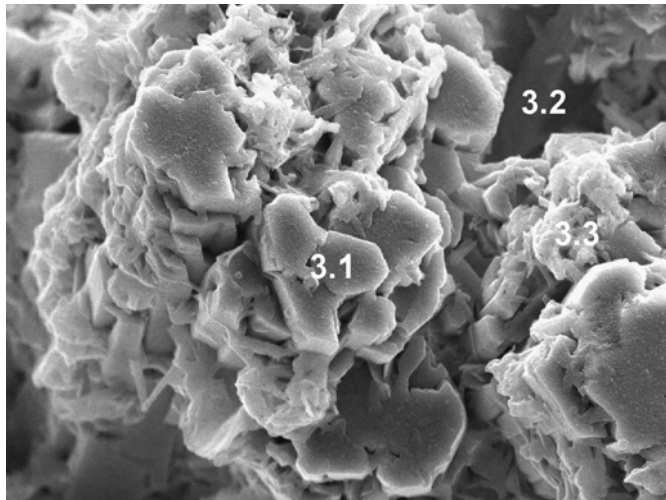
20  $\mu\text{m}$



5000 : 1

b)

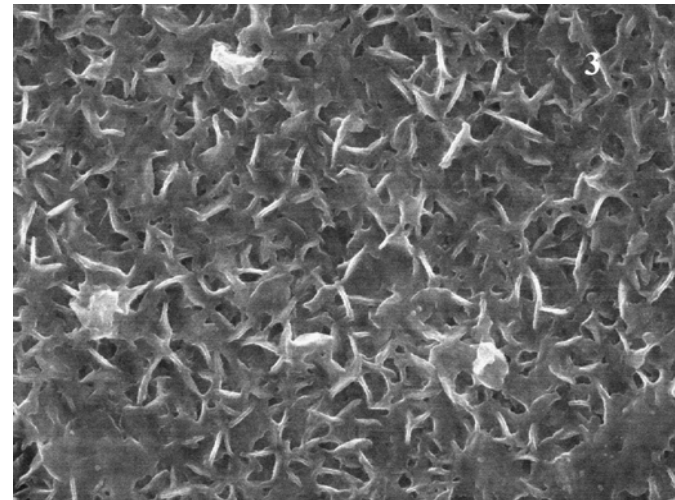
5  $\mu\text{m}$



5000 : 1

c)

5  $\mu\text{m}$



20000 : 1

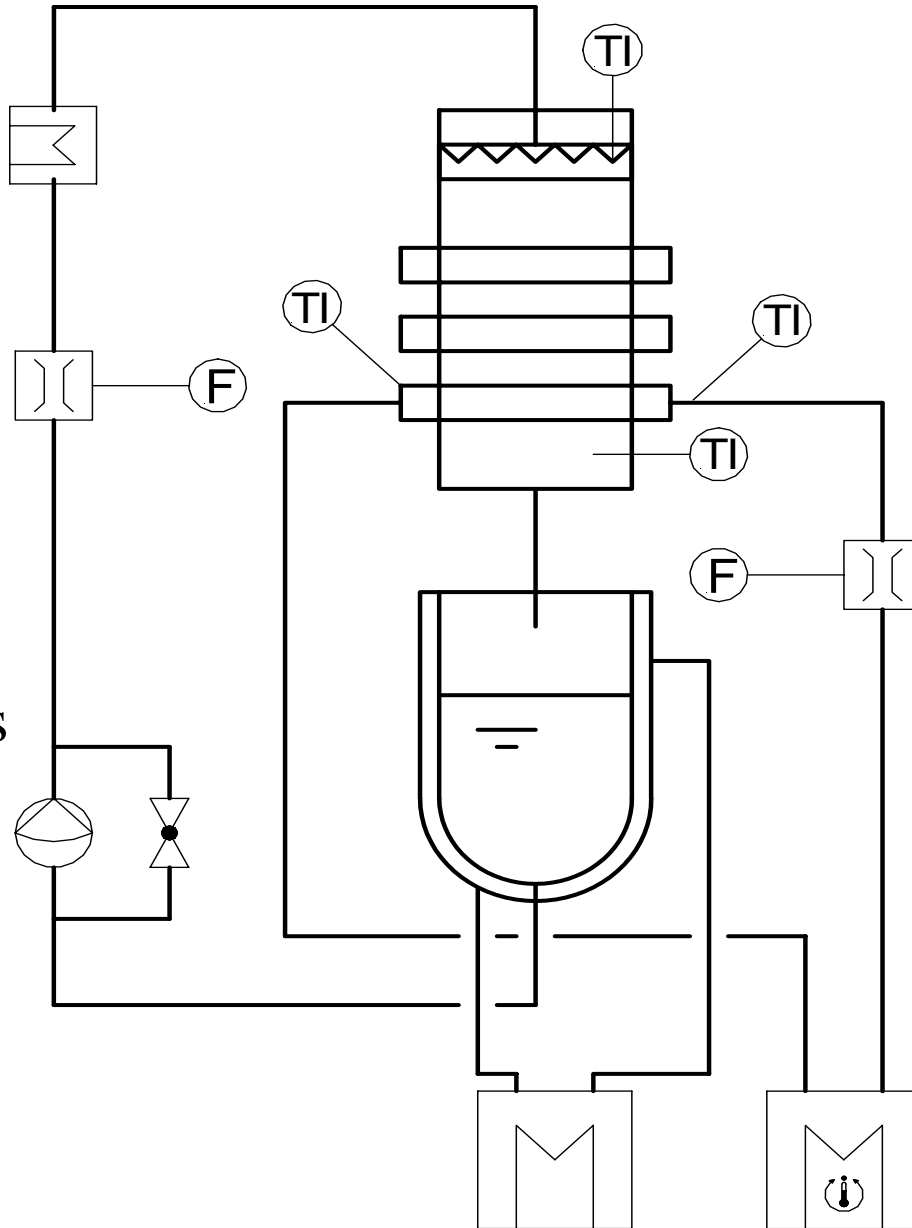
d)

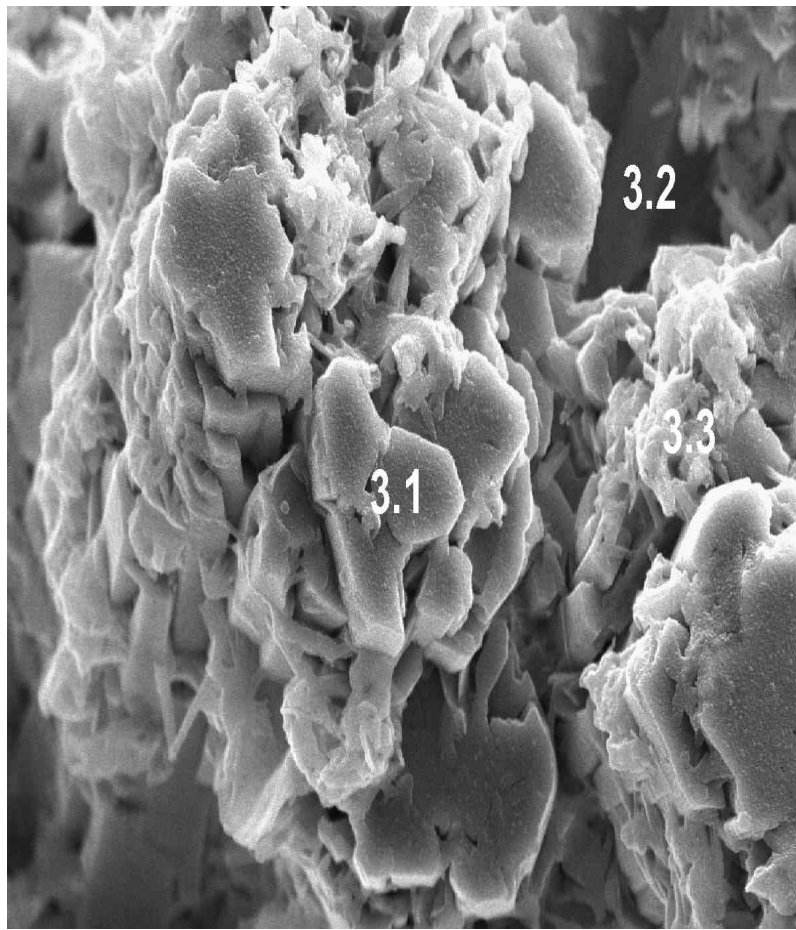
1000 nm

Figure 4: SEM showing the variety of occurring crystals during the evaporation process under varying operation conditions.

# Laboratory plant

- without vacuum
- heating medium: water
- $\Delta T$  not adjustable
- easier handling
- less volume  $\Rightarrow$  less salts

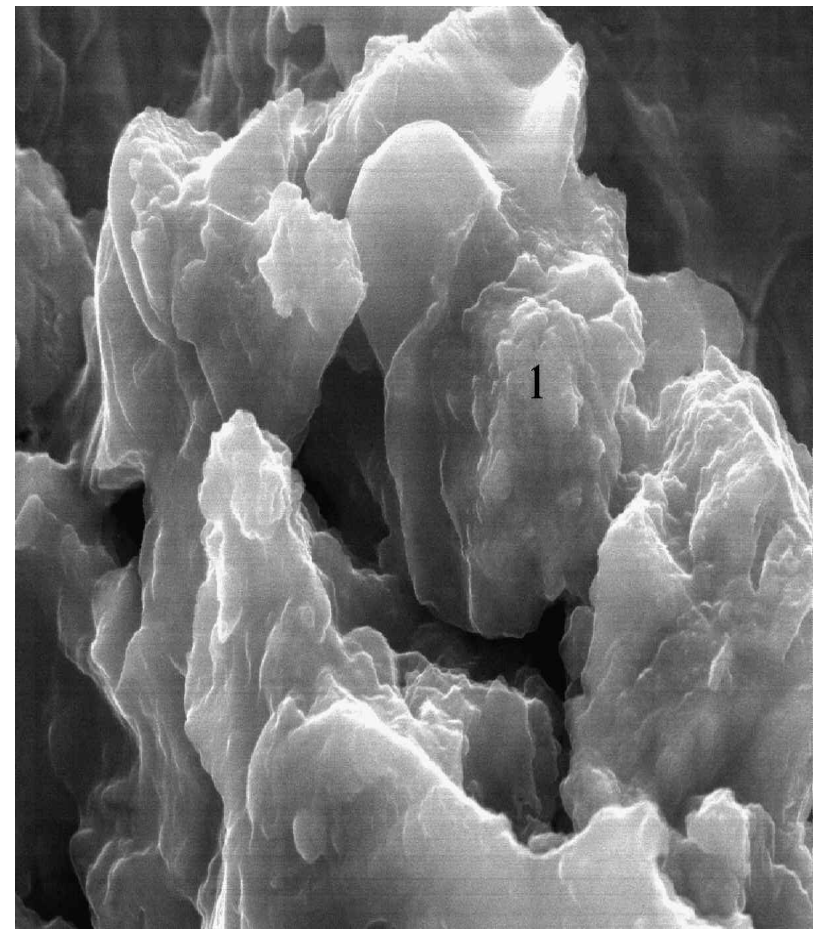




5000 : 1

a)

5  $\mu\text{m}$



20000 : 1

b)

1000 nm

Figure 5: SEM showing crystals formed at high  $\Delta T$  between heating temperature and evaporation temperature. a) from the pilot plant and b) from the laboratory plant



# Conclusions

- satisfactory results of incrustation after 50 h
- expected scale composition
- not depending on salinity
- not depending on temperature level
- strongly depending on operation conditions
  - temperature difference
  - heat flux

A wide variety of operation conditions is necessary to realize authentic scale formation as well as to control and minimize scale formation.

⇒ **a test rig in pilot plant size is inevitable**