ATMOsphere ASIA
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Results of heat exchanger operated in hard water conditions for CO_2 heat pumps

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CHALLENGE EFFICIENCY

SWEP
A DOVER COMPANY

Cost related to fouling- findings from Steinhagen

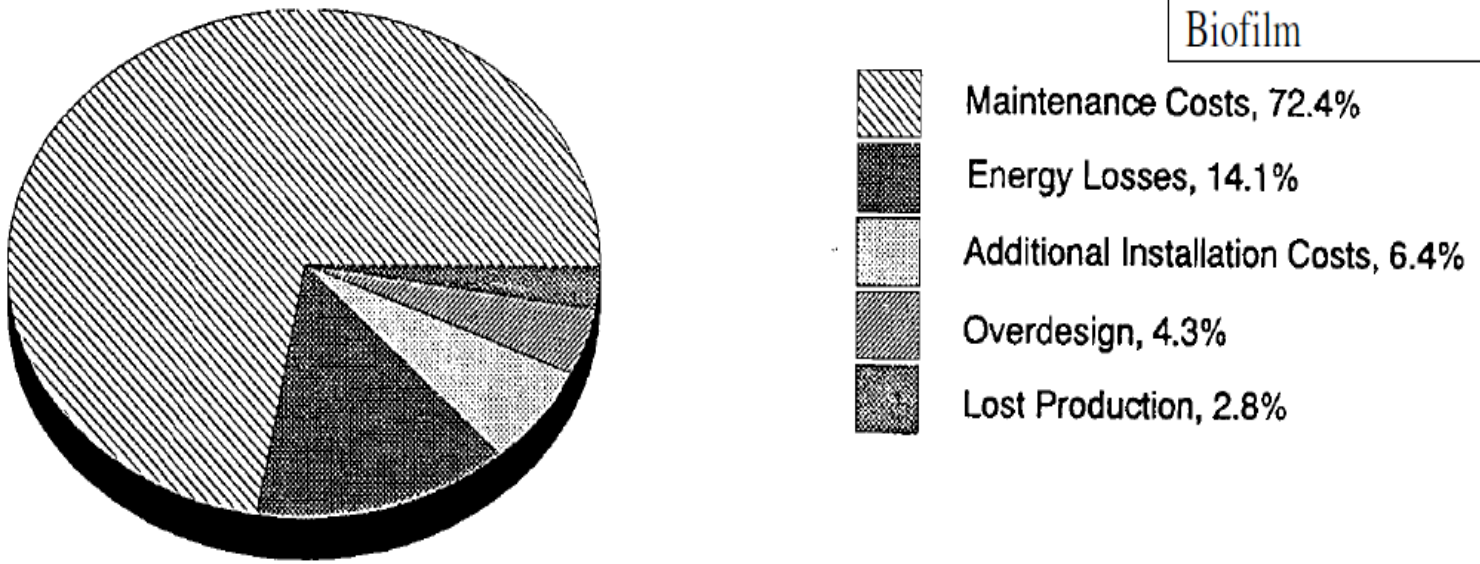
-1-5% of the totoal energy used in industry

- 0,25% of GDP (industrilized countries) are related to fouling

-Capital cost for anti fouling equippment was 1982 alreay 1,3 b.USD in the US

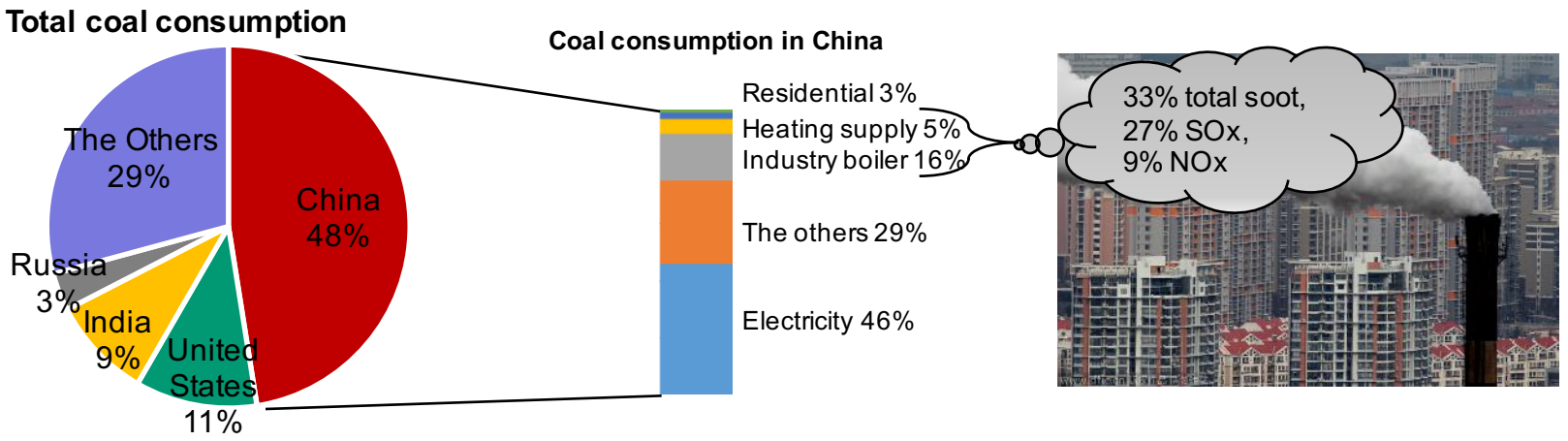
-Cost for production loss was estimated to be 200 Mio. USD in the US

Calcium Carbonate	2.9 W/mK
Calcium Sulphate	2.3 W/mK
Biofilm	0,7 W/mK



Project overview

- China consumes a half of global coal production.
- The coal boiler for heating supply is one of major air pollution sources.



- Clean energy, energy efficiency comparing and heat pump opportunity (over 450.000 units under 10 ton)

Heating 10ton water from 15°C to 55°C per day for a hotel case in East China.

Items	Resource	Efficiency	Primary energy efficiency	Annual fuel consumption	CO2 emission	Fuel cost (RMB)	Labor cost (RMB)	Annual cost (RMB)	System life (Year)	Notes
Coal boiler	Coal	approx. 65%	65%	33Ton	**63Ton**	17K	**20K**	**37K**	5～8	Due to air pollution, small capacity been limited.
Gas boiler	Natural gas	approx. 87%	87%	20Km^3	**40Ton**	88K	**20K**	**108K**	5～15	Obey to safety standard. Promoted by government. Uncertain of gas supply and price.
Electric boiler	Electricity	approx. 94%	**36%**	182MWh	**150Ton**	97K	0	**97K**	10～15	Combined with storage tank, use off-peak electricity. Very low energy efficiency
Heat pump	Electricity	3.5*1)	**131%**	48MWh	**40Ton**	34K	0	**34K**	10～15	Combined with storage tank, use off-peak electricity. High Initial cost, reliability not proved.

*1). According to GB29541-2013, grade 3, heat pump water heater≥10kW

Solution - SWEP product line-up

Gas coolers (Supercritical operation)

Cascade

Evaporators (Subcritical operation)

B9
78.7.5x345

B17
119.5x377

B18
119.5x377

B185
203.2x452.2

B12
117x287

B/V25
119x526

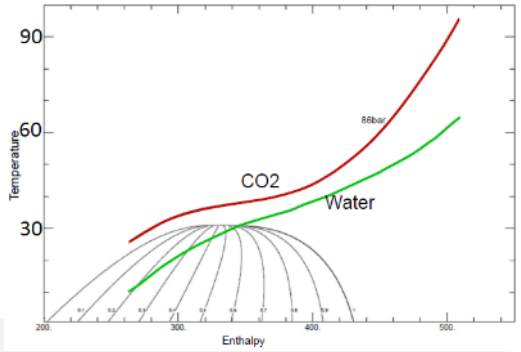
B/V120T
243x525

B/V400
304x694

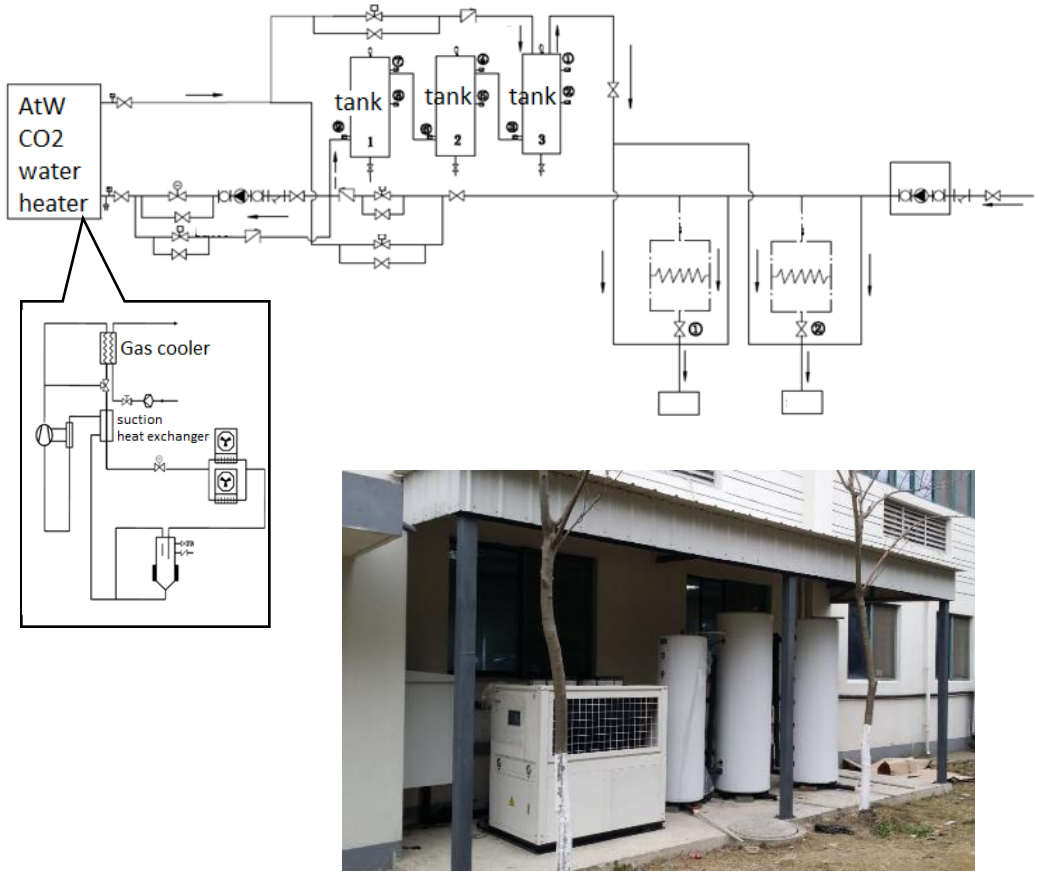
CHALLENGE EFFICIENCY

Field study - CO_2 heat pump water heater application case in China

- Canteen hot water supply by using 25kW CO_2 heat pump with hot water storage.
- Gascooler adopted SWEP B17, to maintain B17 operation in thermal-effectively, cooling water supply used back flush.



Gas cooler, B17, temperature profile of a standard situation



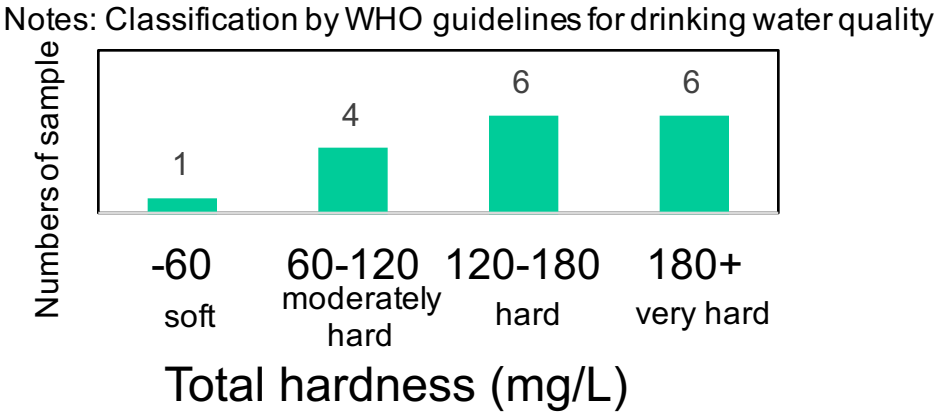
System schematic and installation for Canteen hot water supply

For 7.5hp to 40hp, the market in 2014 is about 400units, and in 2015 is about 500units.

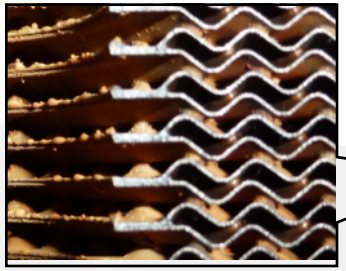
Barriers - City water hardness and heat pump scaling

- Hard and very hard water is main trend in China for city water supply.

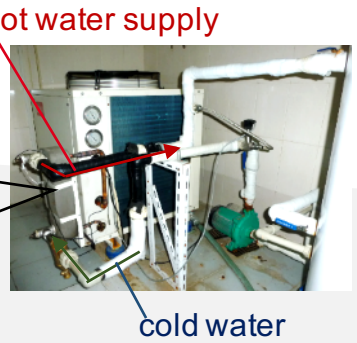
City water sample location

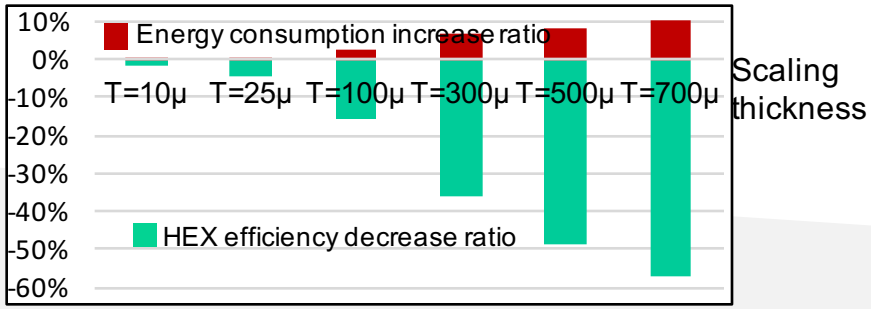


- The hard water cause scaling reduce heat exchangers efficiency.



The heat exchanger cutting piece

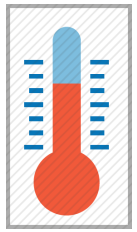




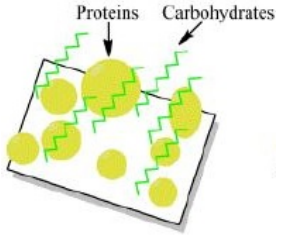
CHALLENGE EFFICIENCY

Fouling: Reasons and Influencing Factors

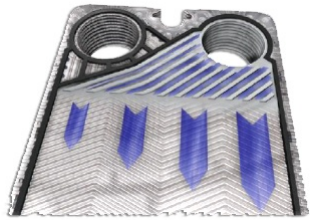
Temperature



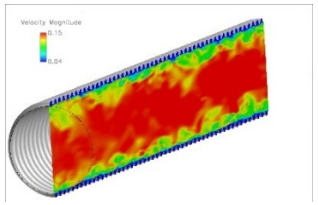
Water composition



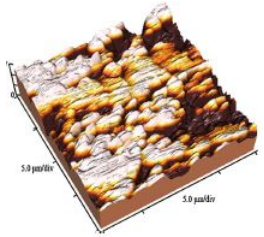
Flow distribution

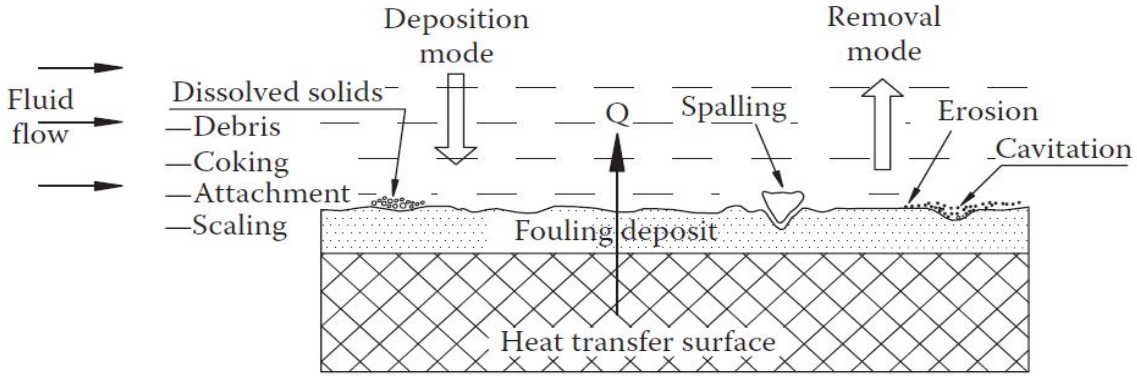


Velocity



Surface





$$\frac{dm_f}{dt} = \dot{m}_d - \dot{m}_r$$

dm_f is fouling rate

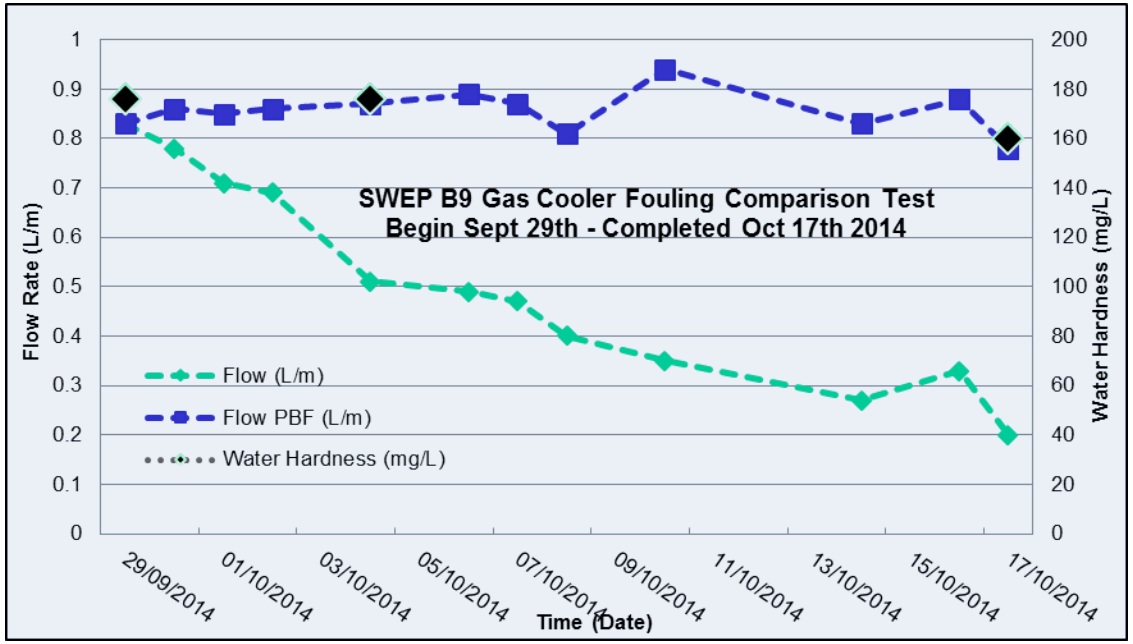
$\dot{m}_d$ is net deposition rate

$\dot{m}_r$ is net removal rate

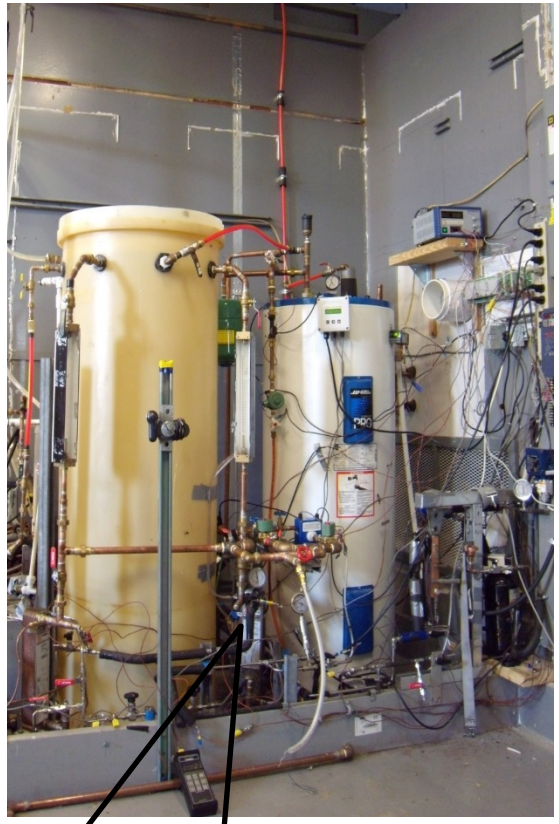
O'Callaghan, M., Fouling of heat transfer equipment: Summary review, in *Heat Exchangers: Thermal-Hydraulic Fundamentals and Design*, S. Kakac, A. E. Bergles, and F. Mayinger, eds., Hemisphere, Washington, DC

Result- Passive Back flush

Accelerated fouling testing of gas cooler



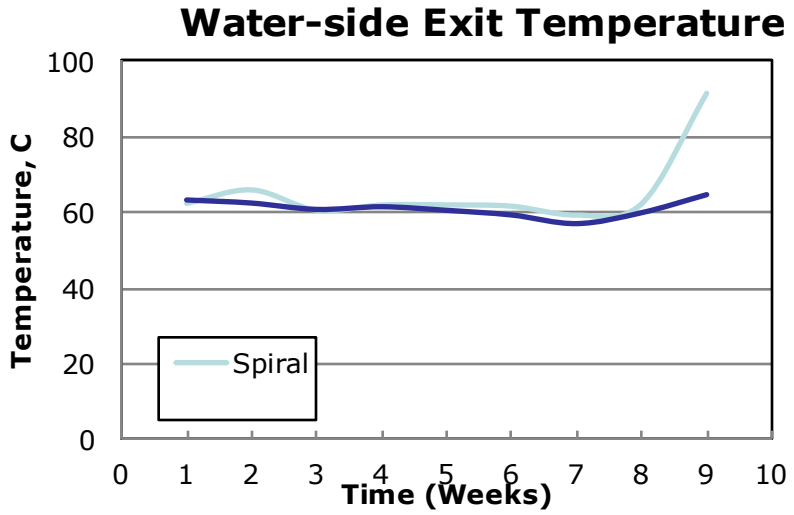
CO2 heat pump BPHE gas cooler in 20days operation. B9 Heat transfer efficiency is only 20-**25%**, comparing normal system with back flush type

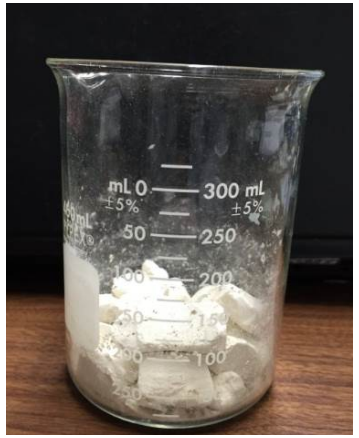


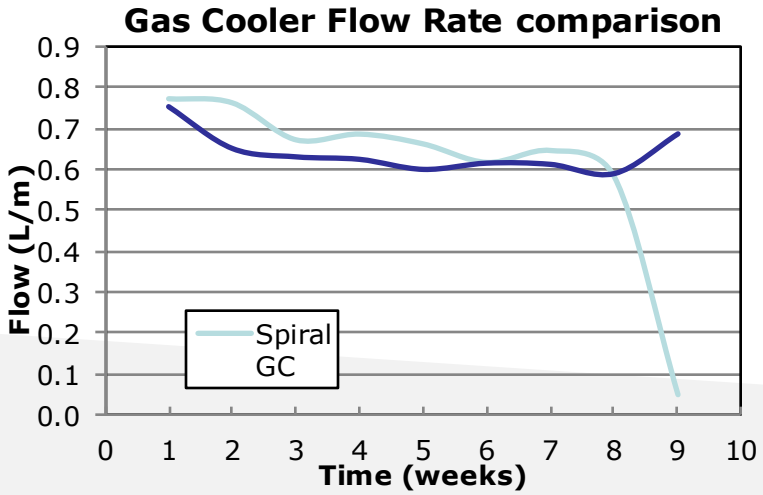
BPHE gas cooler in the system

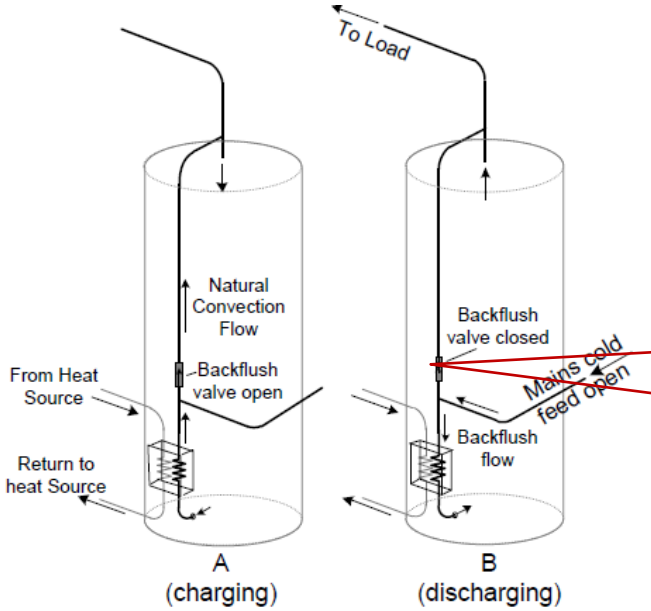
CHALLENGE EFFICIENCY

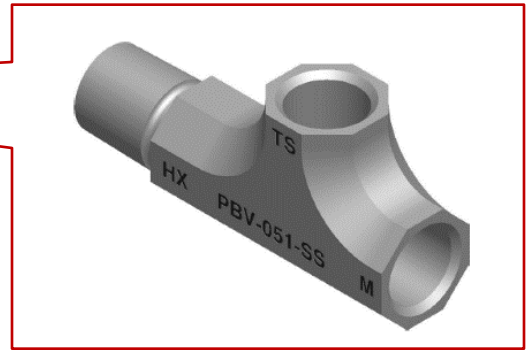
Solution - Back flush by QSBRI











Future plans

- Continue hard water field operation for heat exchanger efficiency study
- Optimize CO_2 heat exchanger design
- Heat exchanger integrated backflush solution for CO_2 heat pump

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Thank you very much!

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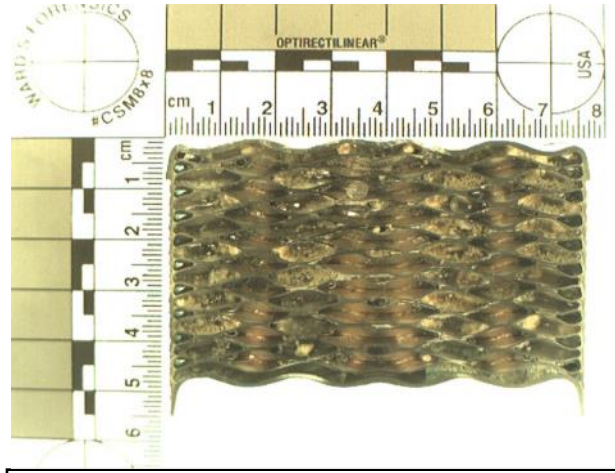
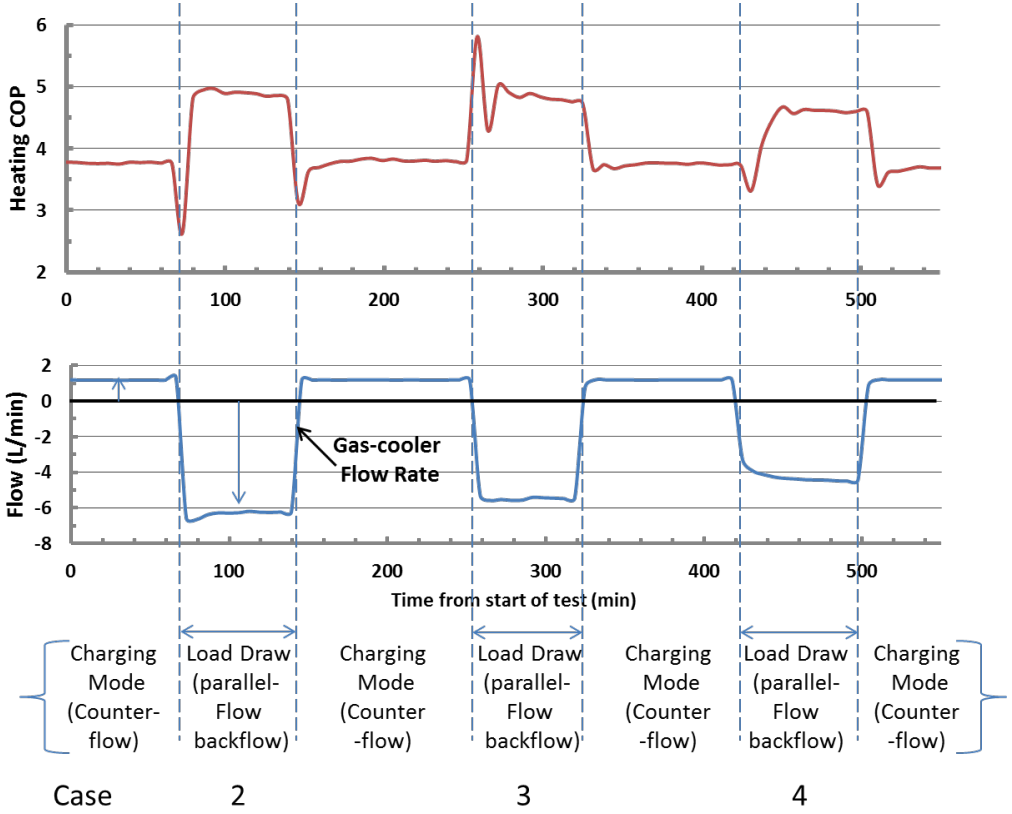
Appendix



Heat Exchanger fouled from incorrect installation of PBF

- PBF showed the additional benefit during test on a natural convection water loop on a CO2 heat pump of increasing the COP by 20 to 25% dependant on draw flow rate*

Example Test Result: shown for 3 Backflow sequences



*Murray, P., Harrison, S., and Stinson, B. (2014) "Evaluation of Passive Anti-Fouling Technology Applied to CO2 Heat Pump Water Heaters," in *ASME 2014 International Mechanical Engineering Congress and Exposition*, Nov 14-20. Montreal, Quebec.