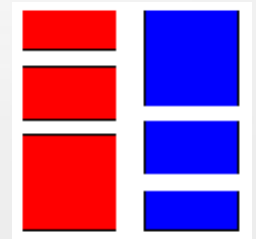


Latest Ultra Low Charge Ammonia Shell and Tube Evaporator

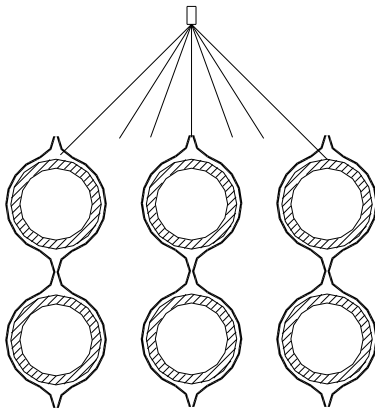
Zahid Ayub, Ph.D., P.E.
Isotherm, Inc.
Arlington, Texas, USA



Preview of Current Low Charge Evaporators

Shell and Tube Spray

- Currently used in various industries
- The only drawback is external pump



Preview of Current Low Charge Evaporators

Plate and Frame

- Commonly used in industrial refrigeration
- Expandability (+ve)
- Multiple gaskets (-ve)
- Higher maintenance cost (-ve)



Shell and Plate

- Not as common
- Non-expandable (-ve)
- Fully welded (+ve)
- Leak potential (-ve)



Preview of Current Low Charge Evaporators

Shell and Tube DX

- Not too common in Ammonia industry
 - Oil
 - Distribution
- Water on shell side
- Cleaning an issue



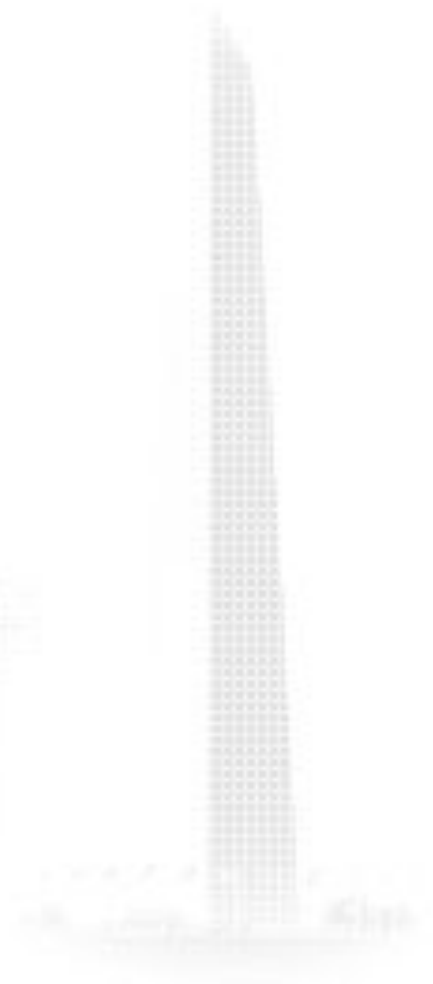
What is SX Chiller?

- Concept of thin film evaporation similar to spray chiller
- Reverse feed
- No pump



Advantages of SX Evaporator

- Mechanical integrity
- High efficiency
- Very low Ammonia charge
- Tubes accessible for cleaning
- Freeze protection
- Simple oil management
- Simple and user friendly controls



Case Studies

A. 385 kW Evaporator - Commercial Fishing Boat - Chile

B. 250 kW RSW Evaporator - Test Stand - Norway



385 kW Commercial Fishing Boat in Chile

Design parameters

Capacity:	385 kW (110 TR)
Sea Water Flow:	180 m ³ /hr (792 gpm)
Sea Water In:	3.33C (38F)
Sea Water out:	0.67C (33.2F)
Ammonia SST:	-4.44C (24F)

Results:

Capacity achieved	
Total Ammonia System Charge:	18 kg (40 lbs)
Service “U” Value:	340 Btu/hr/ft ² /F (1938 W/m ² /C)



250 kW RSW Test Stand in Norway

Design parameters

Capacity:	250 kW (71 TR)
Sea Water Flow:	180 m ³ /hr (793 gpm)
Sea Water In:	0.17C (32.3F)
Sea Water out:	-1.0C (30.2F)
Ammonia SST:	-5.0C (23F)

Results:

Sea Water Flow:	208 m ³ /hr (916 gpm)
Sea Water In:	0.4C (32.7F)
Sea Water out:	-0.6C (30.9F)
Ammonia SST:	-3.9C (25F)

Total Ammonia System Charge: 35-40 kg (77-88 lbs)
Service “U” Value: 477 Btu/hr/ft²/F (2719 W/m²/C)



Raw Data

Date	Time	RSW Setpoint [°C]	RSW Temp Out [°C]	RSW Temp In [°C]	Suction Temp [°C]	Comp. Capacity [%]
5/23/2012	11:04:33	-1.5	2	3.1	-3	99
5/23/2012	11:05:33	-1.5	1.9	2.9	-3.2	99
5/23/2012	11:06:33	-1.5	1.7	2.8	-3.4	99
5/23/2012	11:07:33	-1.5	1.6	2.6	-3.6	99
5/23/2012	11:08:33	-1.5	1.4	2.5	-2.8	99
5/23/2012	11:09:33	-1.5	1.2	2.3	-2.5	99
5/23/2012	11:10:33	-1.5	1.1	2.1	-2.6	99
5/23/2012	11:11:33	-1.5	0.9	1.9	-2.8	99
5/23/2012	11:12:33	-1.5	0.7	1.8	-2.9	99
5/23/2012	11:13:33	-1.5	0.6	1.6	-3	99
5/23/2012	11:14:33	-1.5	0.4	1.4	-3.2	99
5/23/2012	11:15:33	-1.5	0.3	1.3	-3.3	99
5/23/2012	11:16:33	-1.5	0.1	1.1	-3.4	99
5/23/2012	11:17:33	-1.5	0	1	-3.5	99
5/23/2012	11:18:33	-1.5	-0.2	0.8	-3.6	99
5/23/2012	11:19:33	-1.5	-0.3	0.7	-3.8	99
5/23/2012	11:20:33	-1.5	-0.5	0.5	-3.9	99
5/23/2012	11:21:33	-1.5	-0.6	0.4	-4	100
5/23/2012	11:22:33	-1.5	-0.8	0.2	-4.1	100
5/23/2012	11:23:33	-1.5	-1	0.1	-4.2	100
5/23/2012	11:24:33	-1.5	-1.1	-0.1	-4.3	100

250 kW RSW Test Stand in Norway

Temperature pull down

Number of water tanks: 4

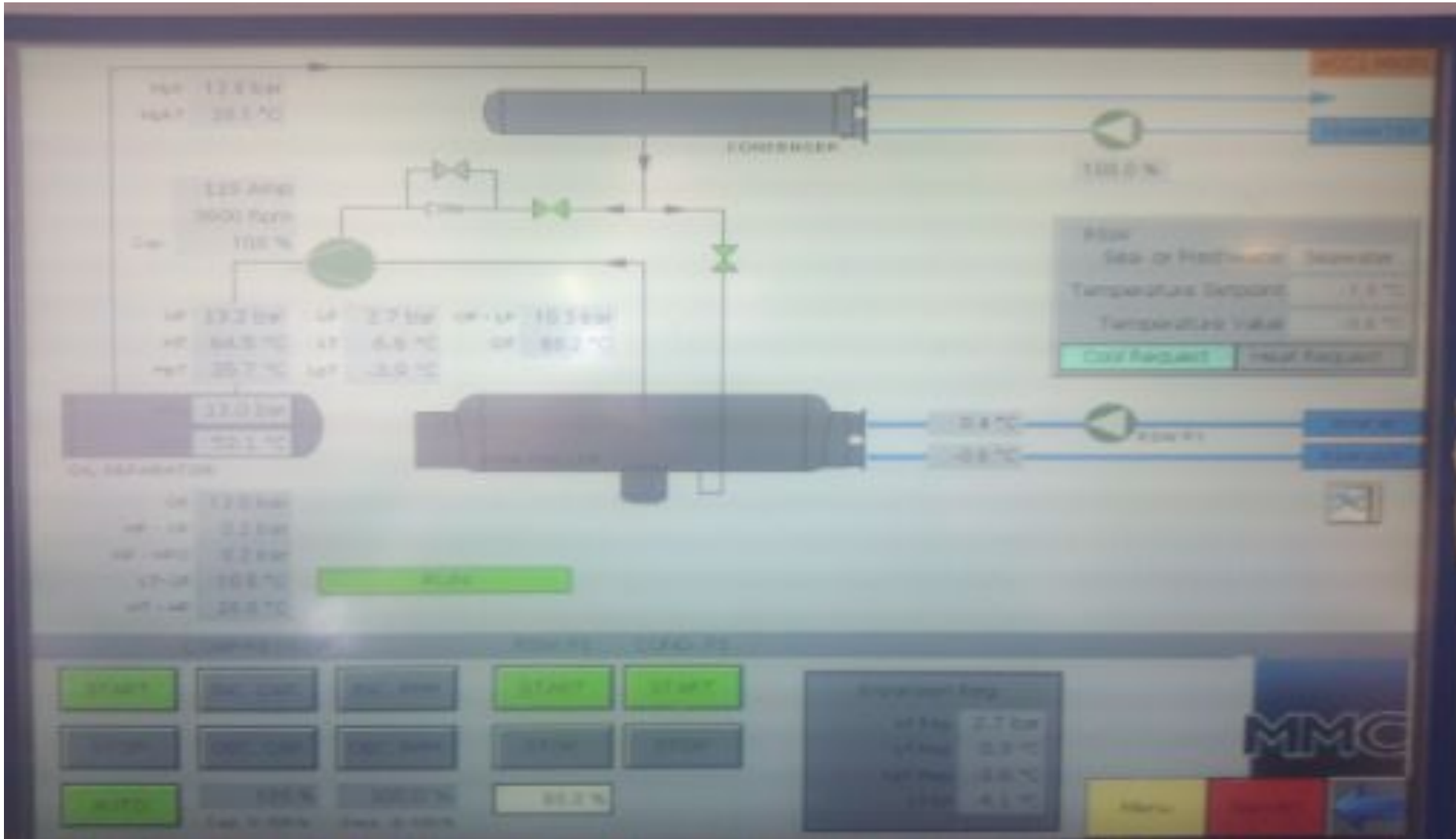
Capacity of each tank: 3,200 liters (850 gallons)

Pull down time: 35 minutes

Temperature pull down: 11C to -1.0C (51.8F to 30.2F)



250 kW RSW Test Stand in Norway



Comparison : Capacity 385 kW – same temperature and flow conditions

	S&T Flooded	S&T Spray	PHE Flooded	S&T New
Geometry	w/integral separator	w/drop leg	w/top Separator	No separator No drop leg
Tube length	3048 mm	3048 mm	-	3048 mm
Service “U”	1675 W/m2-K	2475 W/m2-K	1835 W/m2-K	1938 W/m2-K
“U” Normalized to Flooded	1	1.48	1.10	1.15
Charge	155 kg	80 kg	200 kg	18 kg
kg/kW	0.40	0.21	0.52	0.05
Normalized Charge	8.6	4.4	11.1	1.0
Price	\$33,000	\$43,000	\$32,000	\$29,000

Conclusions

- Under current situation Ammonia can play a vital role
- To overcome toxicity issue, systems **MUST** be designed to reduce charge within orders of magnitude
- A new novel Shell and Tube evaporator has been developed and tested
- Thermal performance results are highly encouraging
- Ammonia charge relative to existing evaporator technologies is very low
- Shell and tube geometry gives it a “time-tested” ruggedness
- Tubes fully accessible
- Good freeze protection capability
- Simple oil management
- Simple controls

Thank you!

Questions?