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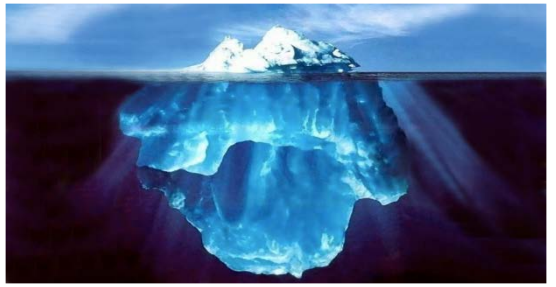
Use of water as a refrigerant

Johnson Controls

Water is many things

Water is a natural and green refrigerant
Most living creatures need water including humans
Most of the water available is salt water

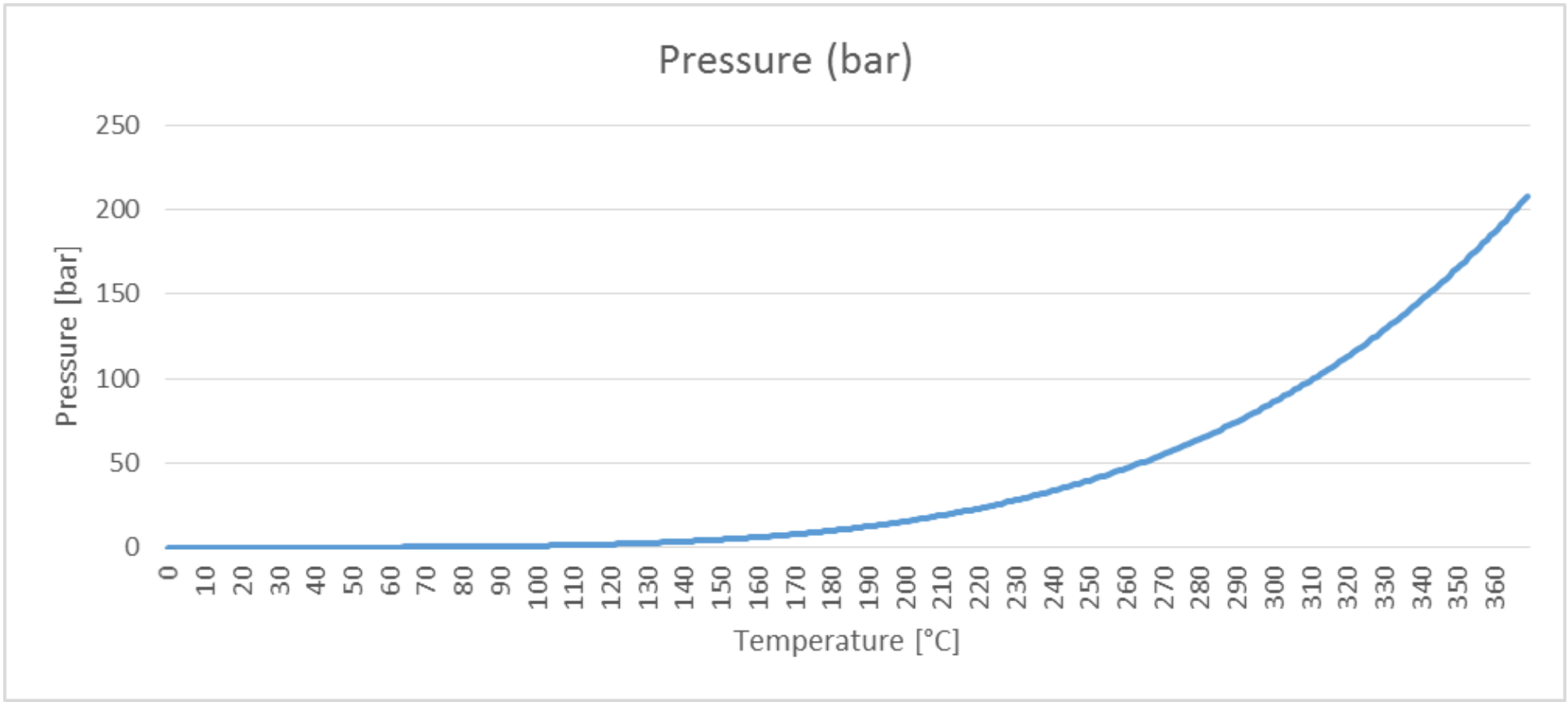
But water can also be dangerous:
Water can be frozen to ice
Water can be full of sharks
Water can be full of rocks that can make ships sink
Water can be full of harmful chemical
More people drawn every year than are killed by all other refrigerants together
Only a little part of all water is not salted
Potable water is unevenly distributed globally



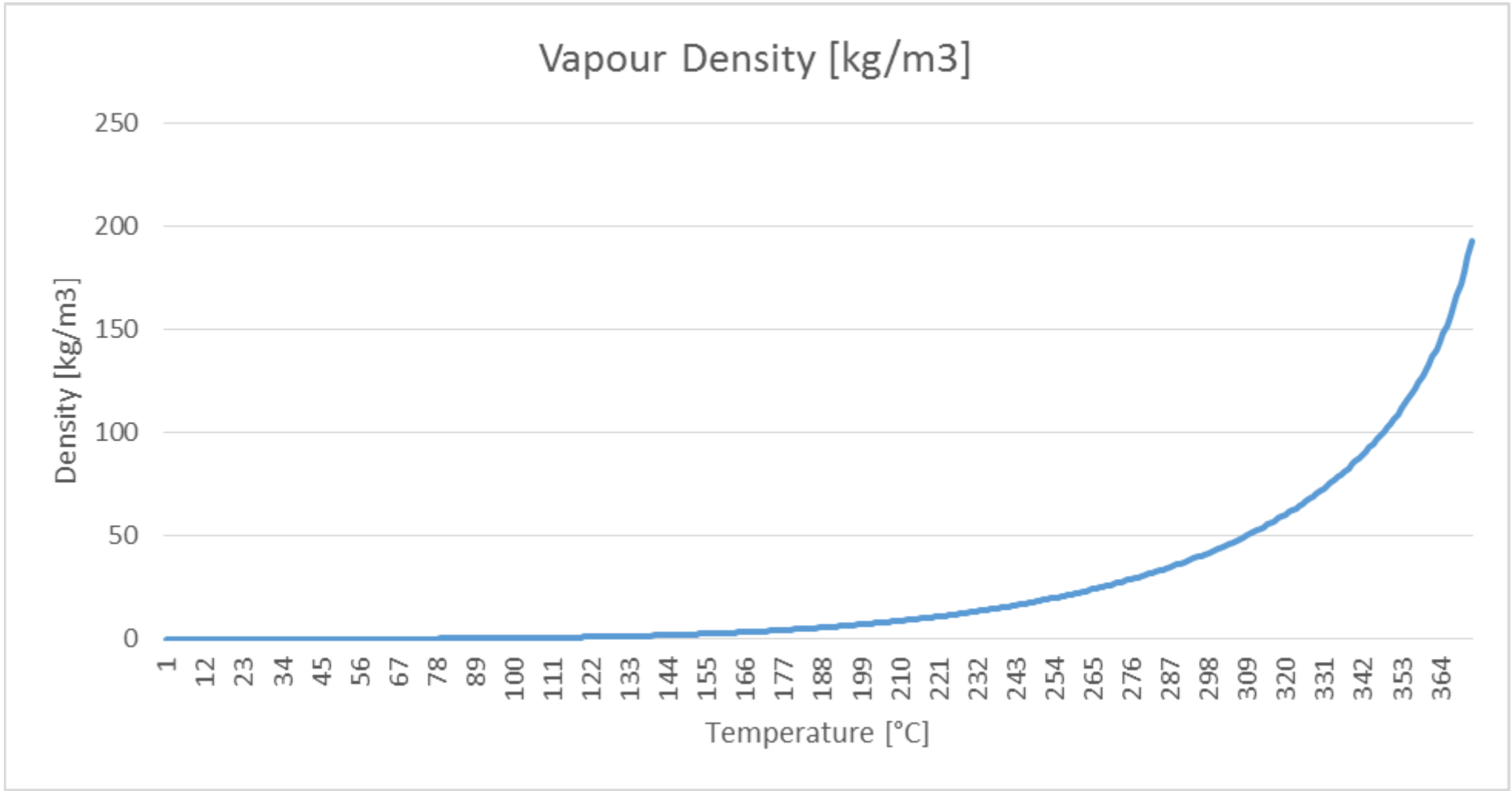
Water has some interesting properties

	kJ/kg	Critical temperature °C	Critical pressure bar	Atmospheric boiling point °C	Molar mass M kg/kmol
Water	2257	373.95	221.2	100	18.015
Ammonia	1367	132.35	11.28	-33	17.03
CO2	574	31.05	73.9	-78	44.01
Propane	428	96.85	42.6	-44	44,097
R22	232	96.15	49.9	-40.81	86.42
R134a	215.9	100.95	40.6	-26.55	102.03
R32	360.24	78.4	53.8	-51.65	52.02
R600a	365.1	134.66	36.29	-11.75	58.122

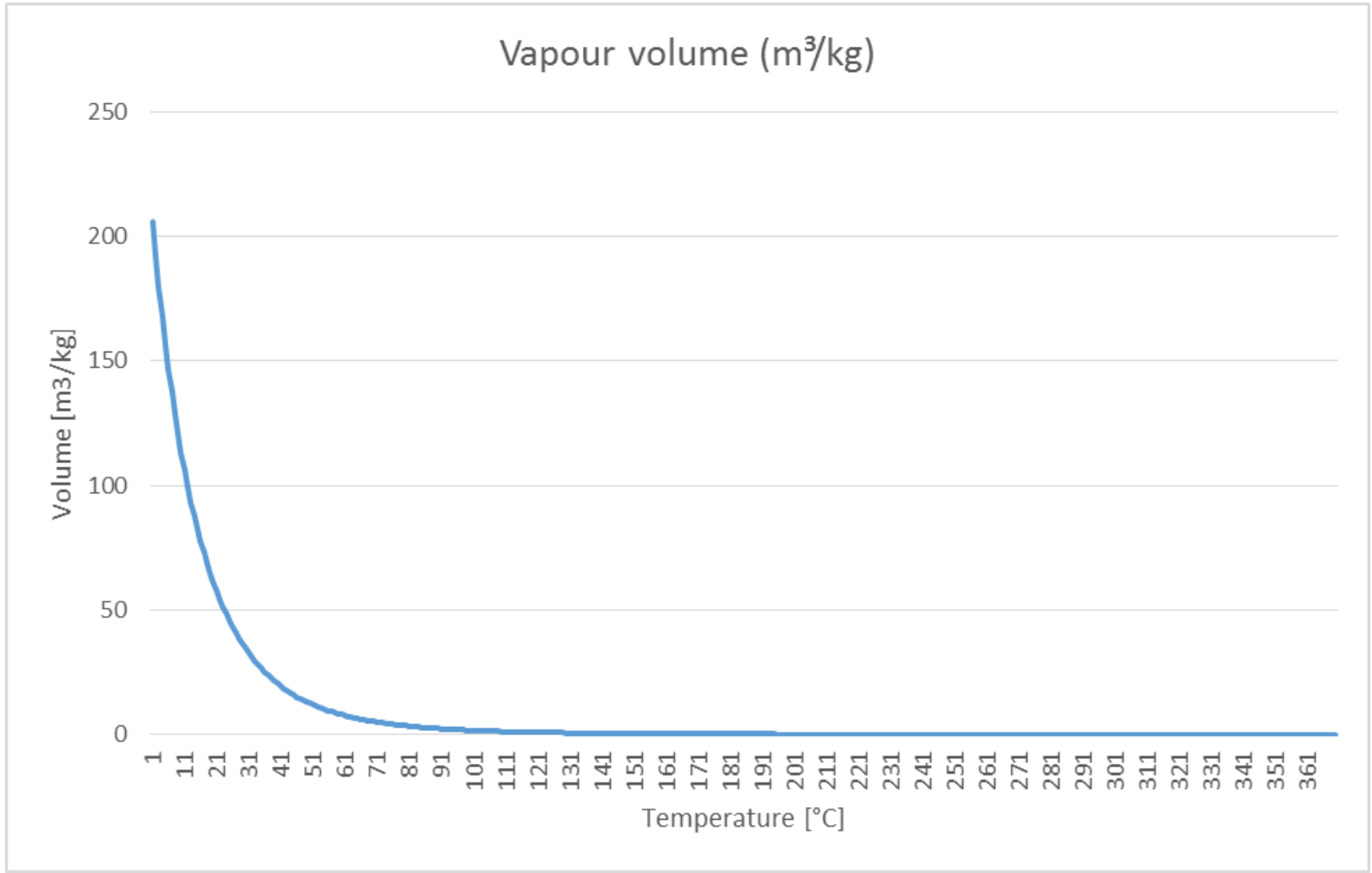
Temperature and pressure relationship



Vapour density



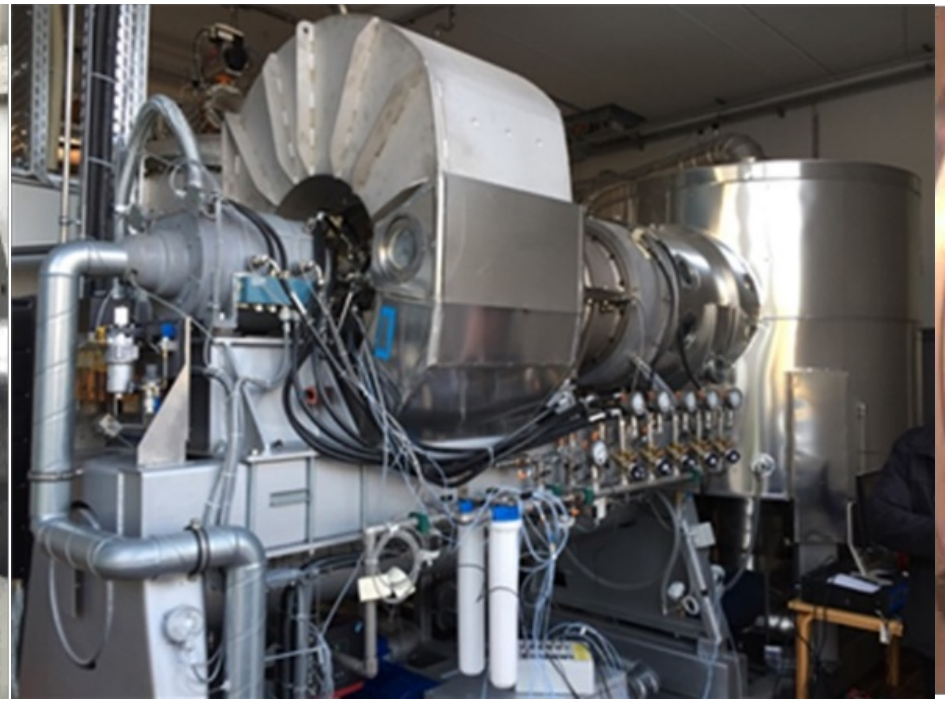
Water vapour volume



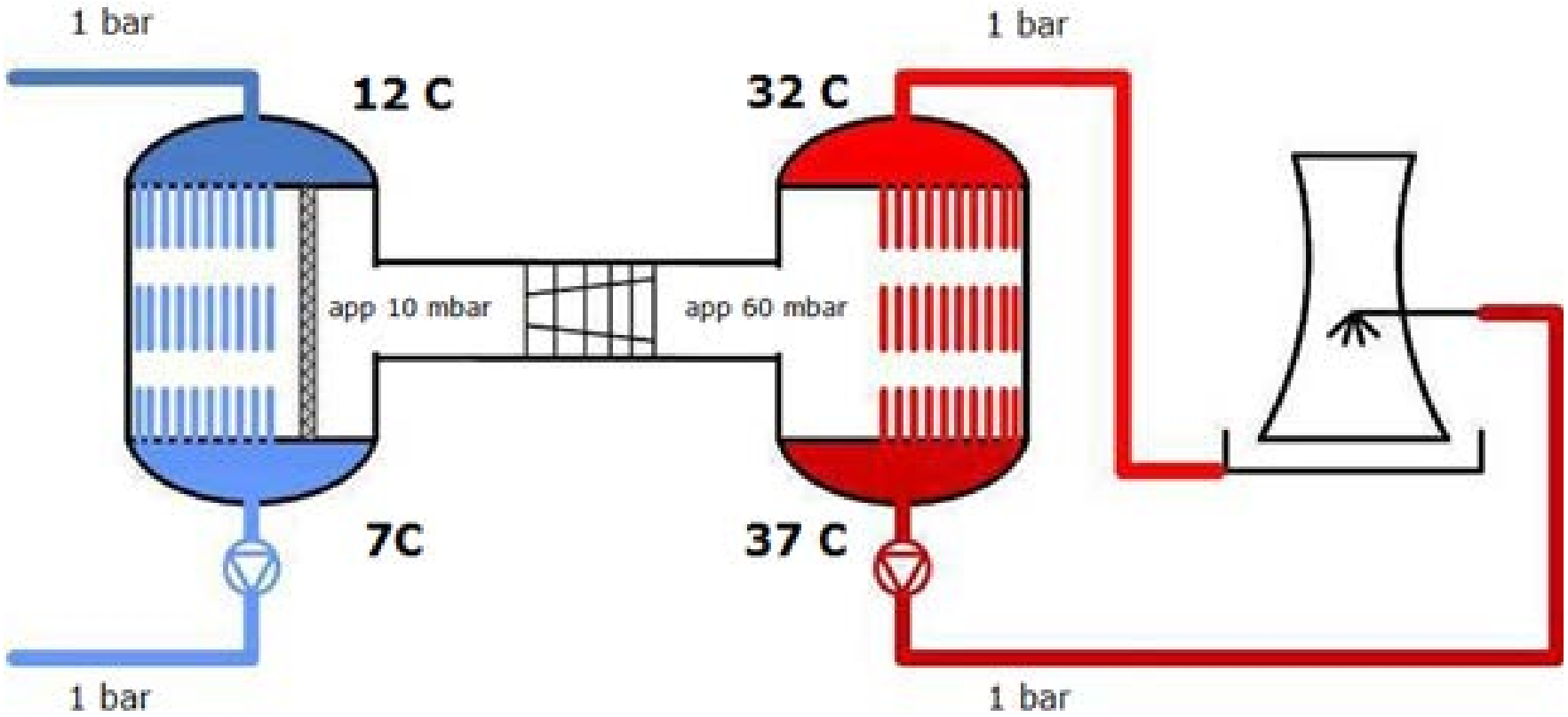
Some selected data for water

Temperature (°C)	Pressure (bar)	Vapor Density (kg/m³)	Vapor Volume (m³/kg)	Heat of Vapor. (kJ/kg)
0,01	0,006117	0,004855	205,99	2500,9
6,01	0,00936	0,007271	137,54	2486,6
9,01	0,011491	0,008832	113,23	2479,5
13,01	0,014991	0,011362	88,01	2470,1
25,01	0,031718	0,023088	43,313	2441,7
30,01	0,042494	0,030432	32,86	2429,8
35,01	0,056321	0,039695	25,192	2417,9
40,01	0,073889	0,051268	19,505	2406
60,01	0,19956	0,13048	7,6639	2357,6
70,01	0,31214	0,19851	5,0375	2333
100,01	1,0145	0,59837	1,6712	2256,4
130,01	2,7036	1,4974	0,66782	2173,7
150,01	4,7629	2,5487	0,39235	2113,7
180,01	10,03	5,16	0,1938	2014,1
200,01	15,553	7,8626	0,12718	1939,7

The axial field-test unit



The principle in the system



Preliminary meassurements

Cooling capacity including lubricant cooling	811.6	kW
Compressor shaft power	139.8	kW
Power input to compressor and vacuum system	153,3	kW
Total power input to unit including water pumps, etc.	182.2	kW
Evaporator inlet (plate heat exchanger in)	12 (20)	
Evaporator out, Te (plate heat exchanger out)	7.5 (9.2)	C
Condenser in	25.5	C
Condenser out, Tc	31.2	C
EER (Power input to compressor and vacuum system)	5.29	

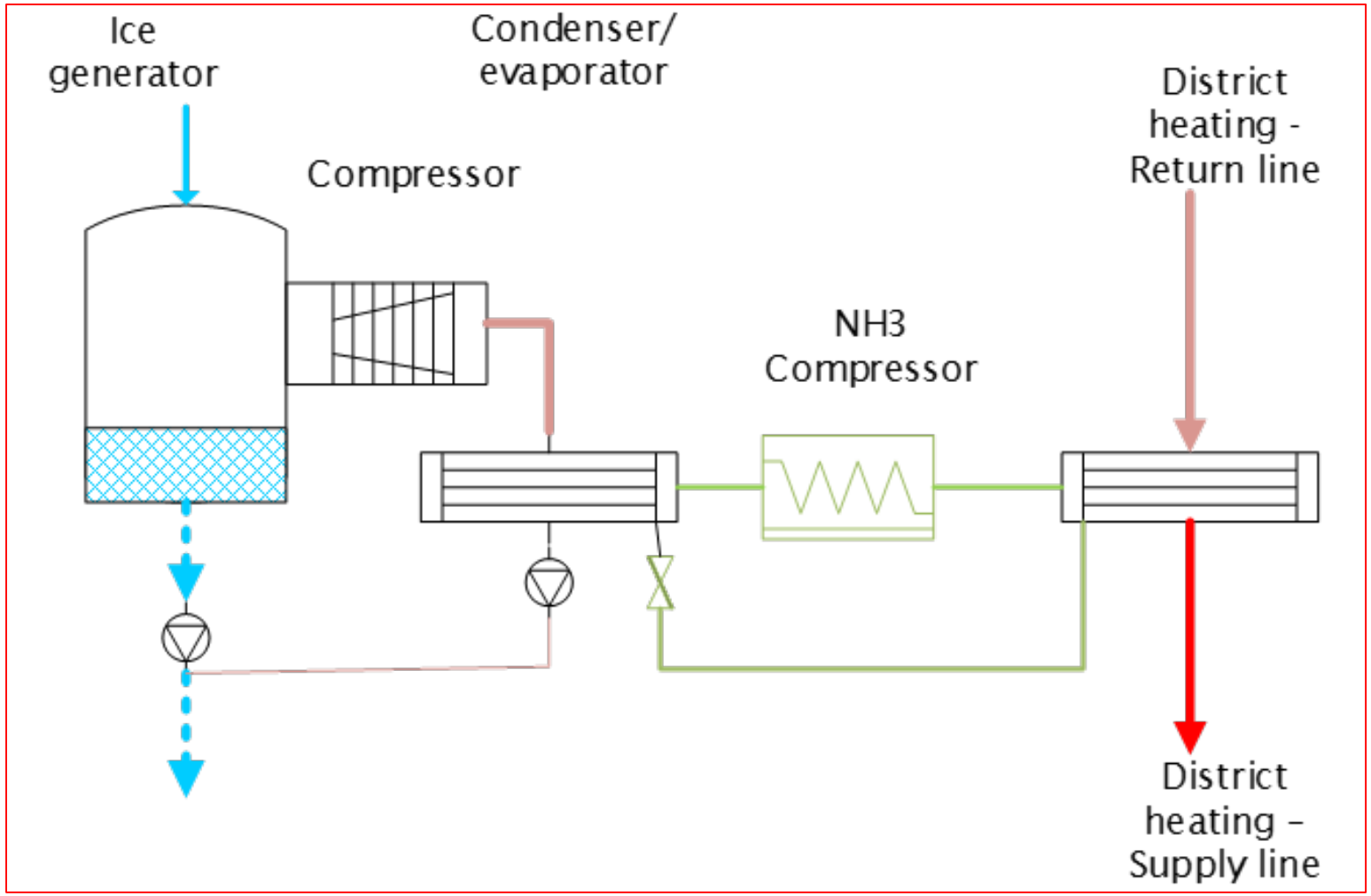
How does it compare?

	H_2O prototype industrial chiller		SABlight Propane chiller
Evaporator	Open	Closed	Closed
Condenser	Closed (dry cooler)	Closed (dry cooler)	Closed (dry cooler)
To in	18	18	18
To out	13	13	13
Tc in	40	40	40
Tc out	45	45	45
Cooling capacity	1170 kW	1030 kW	477 kW
Power input inverter, vacuum, etc.	240 kW	229 kW	123 kW
COP (compressor, vacuum, etc.)	4.88 (5.27*)	4.50 (4.84*)	3.88

Open or closed?

Evaporator	Open	Closed	Open	Closed	Open	Closed
Condenser	Open (cooling tower)	Open (cooling tower)	Closed (dry cooler)	Closed (dry cooler)	Open	Open
To in	18	18	18	18	12	12
To out	13	13	13	13	7	7
Tc in	23	23	40	40	32	32
Tc out	28	28	45	45	37	37
Cooling capacity	1170 kW	1030 kW	1170 kW	1030 kW	820 kW	715 kW
Compressor shaft power	115 kW	115 kW	220 kW	210 kW	155 kW	150 kW
Power input inverter, vacuum etc.	127 kW	127 kW	240 kW	229 kW	170 kW	164 kW
Total power input	160 kW	160 kW	272 kW	262 kW	203 kW	197 kW
COP (compressor, vacuum, etc.)	9.24	8.13	4.88	4.50	4.83	4.35
COP (total input)	7.33	6.45	4.29	3.93	4.05	3.62
COP* (re-design thrust bearing)	8.09	7.12	4.54	4.17	4.37	3.92

Future projects



Thank you for your attention