Absorption chiller
&
Solar Cooling

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Outline

- Absorption chiller
  - Concept of operation
  - Types
  - Market overview
- Solar cooling
  - Basic concept
  - Current status and perspective
  - Practical examples
    - Single effect for air-conditioning
    - Single effect for refrigeration
    - Double effect for air-conditioning

Introduction

1. Absorption cooling was invented by the French scientist Ferdinand Carré in 1858

2. Vapor /Vapour absorption refrigeration systems (VARS) belong to the class of vapor cycles, similar to vapor compression refrigeration systems (VCRS).

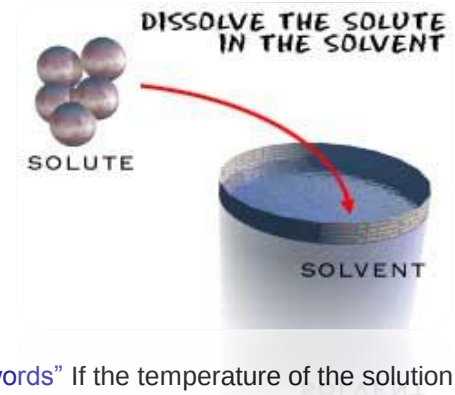
3. Absorption refrigerators are a popular alternative to regular compressor refrigerators where:
   1. electricity is unreliable, costly, or unavailable,
   2. where noise from the compressor is problematic,
   3. where surplus heat is available.

3. The main difference between the two types is the way the refrigerant is changed from a gas back into a liquid so that the cycle can repeat.

4. Since conventional absorption system use natural refrigerants such as water or ammonia they are environment friendly.

Basic concepts

- When a solute (e.g. lithium bromide salt) is dissolved in a solvent (e.g. water) the boiling point of the solution is elevated.

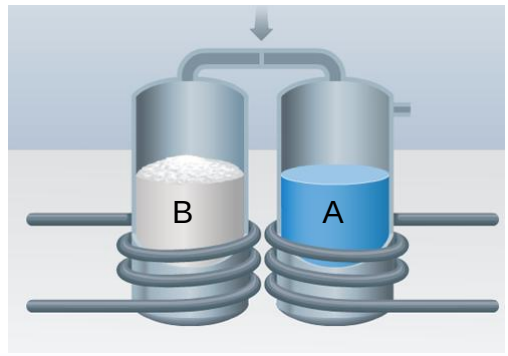


- "In other words" If the temperature of the solution is held constant, then the effect of dissolving the solute is to reduce the vapor pressure of the solvent below that of its saturation pressure at that temperature.

Basic concepts (Contd.)

Refrigeration is obtained by connecting two vessels, with one vessel containing pure solvent (refrigerant) and the other containing a solution (refrigerant +absorbent).

B
50% of LiBr
solved in H_2O
@ 30 ^{0}C
1.22 kPa

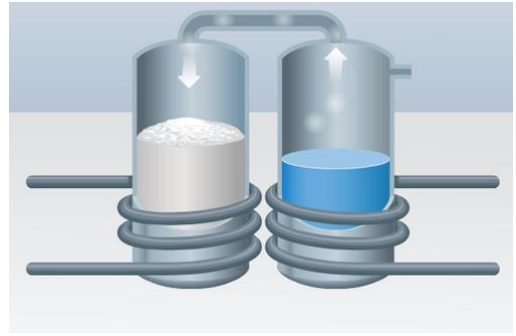


A
Pure water
30 ^{0}C
4.24 kPa

System is in thermal equilibrium with surroundings. 30 ^{0}C

B

50% of LiBr solved in H_2O @ 30 ^{0}C 1.22 kPa

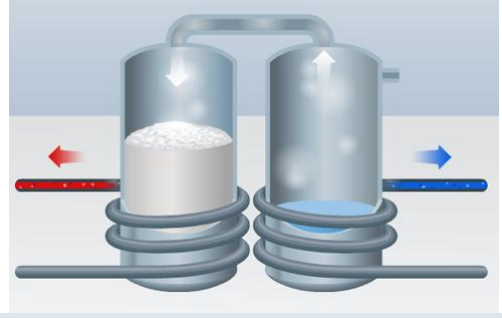


A

Pure water 10 ^{0}C 1.22 kPa

B

Absorber

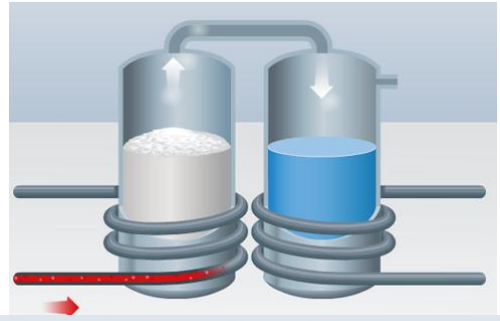


A

Evaporator

We have, in fact, created a heat pump. A coiled tube connects both bowls to two different objects outside the system. Water can be circulated to transport energy (hot or cold) out of the system.

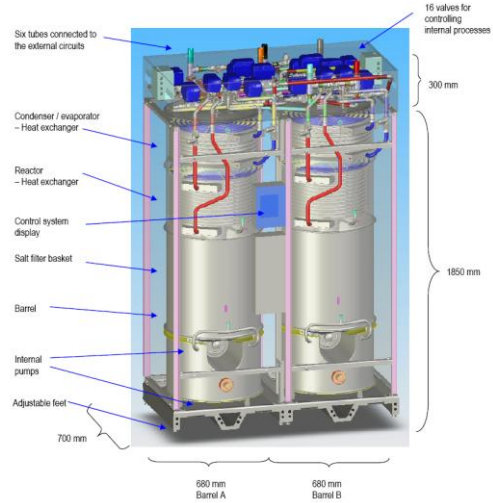
B
Generator



A
Condenser

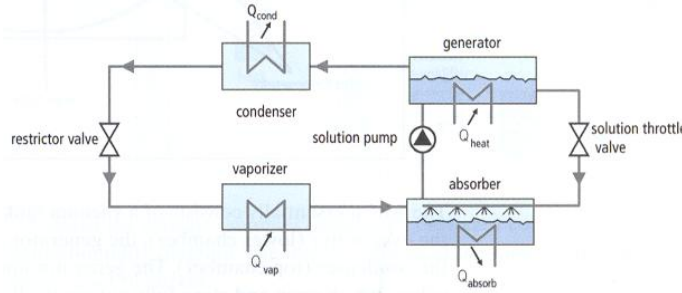
When the salt can´t absorb more water it has to be dried (through warming) to regain its hygroscopic ability. If you heat the salt bowl, the water returns to the water bowl.

Continuous operation using two identical units together



10 kW cooling capacity/ LiCl-H_2O / hot water temp @ 75-105 C / COP_{ele} 333

Continuous operation system



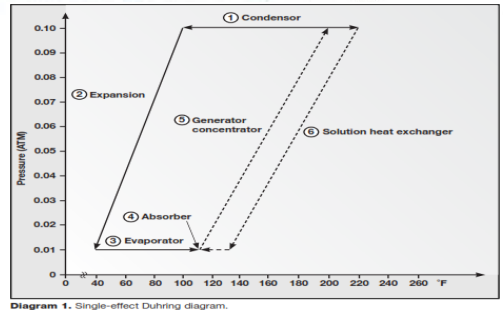


Diagram 1. Single-effect Duhring diagram.

Thermally driven cooling - Overview

Type of system	Water chillers (closed thermodynamic cycles)							Direct air treatment (open thermodynamic cycles	
Physical phase of sorption material	Liquid				Solid			Liquid	Solid
Sorption material	Water	Lithium-bromide			Zeolite	Silica gel	Lithium-chloride	Lithium-chloride	Silica gel, zeolite, cellulose / lithium-chloride
Refrigerant	Ammonia	Water			Water	Water	Water	Water	Water
Type of cycle	1-effect	1-effect	2-effect	3-effect	1-effect	1-effect	1-effect	Cooled sorption process	Desiccant rotor
COP range	0.5 - 0.75	0.65 - 0.8	1.1 - 1.4	1.6 - 1.8	0.5 -0.75	0.5 - 0.75	0.5 - 0.75	0.7 - 1.1	0.6 - 0.8
Driving temperature range, °C	70 ... 100 120 ...180(1)	70 ... 100	140 ... 180	200 ... 250	65 ... 90	65 ... 90	65 ... 90	60 ... 85	60 ... 80
Solar collector technology(2)	FPC, ETC SAT(1)	FPC, ETC	SAT	SAT	FPC, ETC	FPC, ETC	FPC, ETC	FPC, ETC, SAHC	FPC, ETC, SAHC

1: high temperature lift
2: FPC = flat plate collector; ETC = evacuated tube collector; SAT = single axis tracking collector; SAHC = solar air heating collector

Adsorption

Historical actors…

- 2 commercial systems (Japanese manufacturers)
  - Nishyodo (70-500 kW) => GBU GmbH
  - Maekawa (50-350 kW) => Mycom

From 70 kW to several hundred kW...

Source : UniklinikumFreiburg

New development

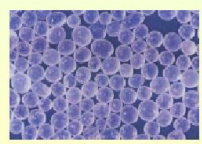
Sortech (Germany) : 10 kW

SorTech AG

Nom. capacity : 10 kW - COP : 0,6
Generator temp. : 80/75°C
Evaporator temp. : 6/12°C
Condensor temp. : 30/35°C
Weight in operation : 180 kg

H2O/Zeolith

H2O/Silicagel



Silicagel => Zeolith

SorTech AG

Source : Sortech

Absorption

Single effect absorption chillers

- Lot of products > 100 kW (Carrier,MacQuay, Toshiba,Hitachi, Ebara, Sulzer Escher Wyss, Trane, LG, Mitsubishi, Entropie,York, Colibri)
- Main chillers used in solar cooling systems :

  YAZAKI WFC SC 10 (35 kW) / Thermax (Spain)
- New machines available on the market :
  - EAW (Westenfeld) : 15 kW
  - Sonnenklima (Berlin): 10 kW
  - Rotartica (Bilbao) : 4,5 kW
  - Climatewell (Sweden/Spain) : 10 kW
  - Pink (Austria) : 10 kW
- Other developments

  FH Stuttgart/Ge, SolarFrost/Au, Aosol/Port, ...

Cention Corp.
105 to 1845 kW (Single effect)

ThermaxIndia

Single Effect Steam Driven Machine

Capacities: From 50 to 2000 TR
Steam pressure: From 0.6 to 3.5 Kg/cm² (g)
Chilled water temperature: Up to 3.5ºC (0ºC for brine)
Heat source: Steam

Double Effect Steam Driven Machine

Capacities: From 51 to 2000 TR
Steam pressure: From 4.0 to 10.0 Kg/cm² (g)
Chilled water temperature: Up to 3.5ºC (0ºC for brine)
Heat source: Steam

Kawasaki, Triple effect chiller

- Freon Free:

Absorption chiller-heaters contain “water” as refrigerant and Freon gas which has high global warming potential, is not used.

- Low Electricity Consumption:

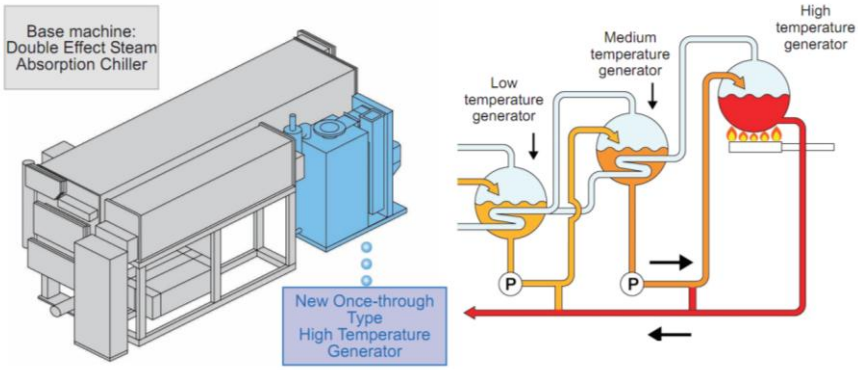
Absorption chiller-heaters provide chilled water by means of natural gas combustion, which contributes to significant reduction of electricity consumption.

- High COP

1.6 (Higher Heating Value basis)
1.7 (Lower Heating Value basis)

Basic Concept or Summary

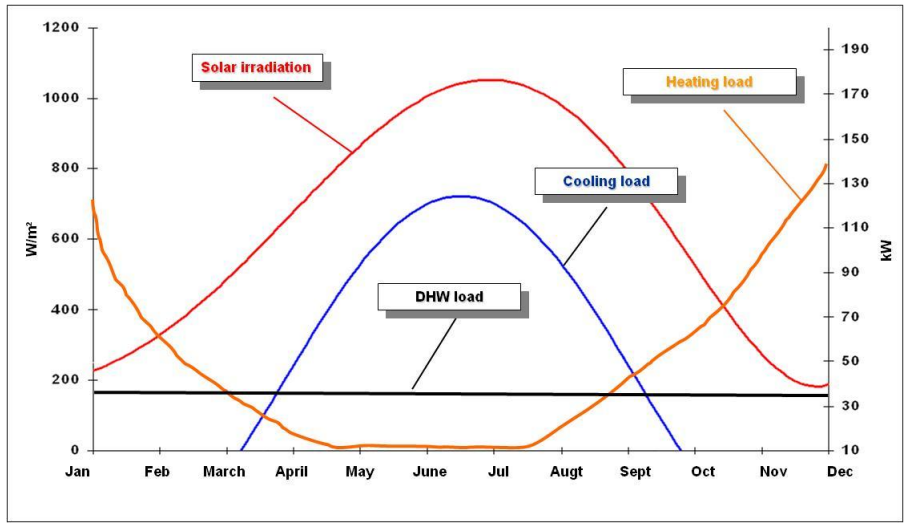
Construction of the triple effect absorption chiller-heater (Image)



- The triple effect absorption chiller-heaters have three generators and lithium bromide solution is generated in three steps.
- The triple effect absorption chiller-heaters have been developed by combination of a double effect steam fired absorption chiller as a base machine and a once-through boiler as a new high temperature generator.

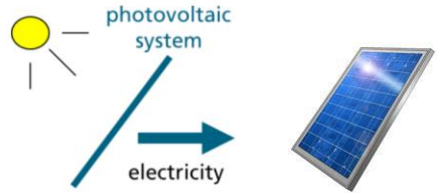
New developments of small capacity water chillers

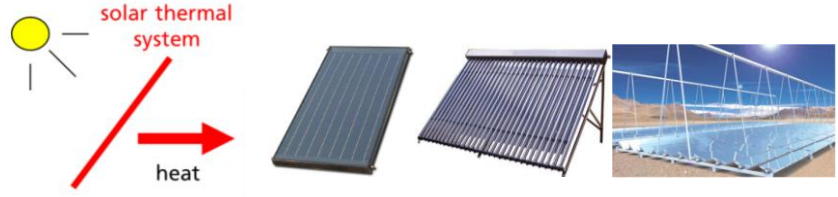
Why solar cooling is interesting?

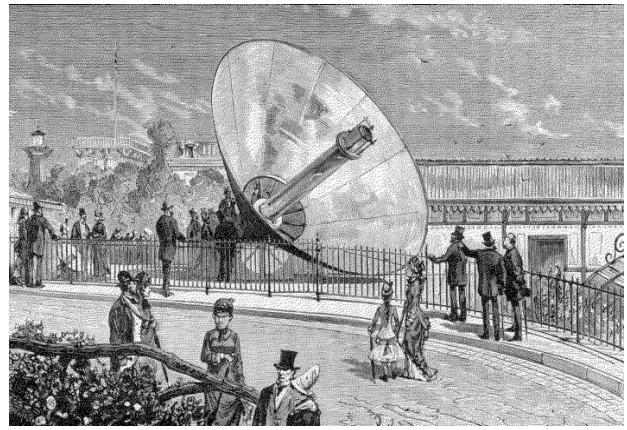


Tecsol

Utilization of solar energy



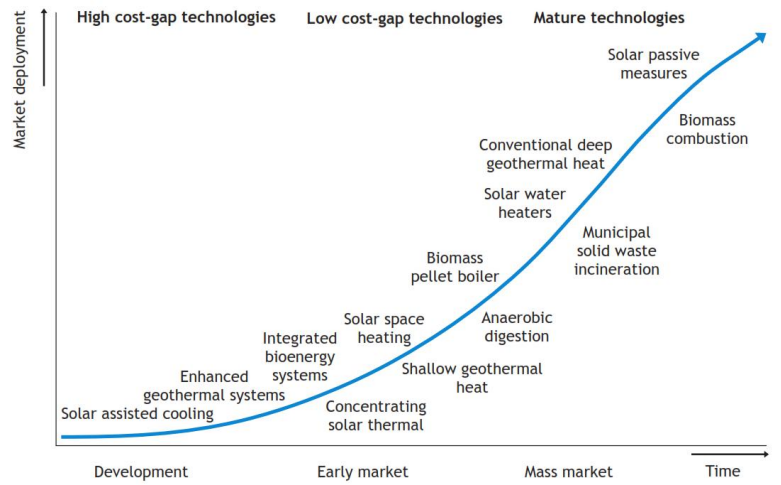




World exhibition 1878, Paris: Augustin Mouchot produced the first ice block through solar energy

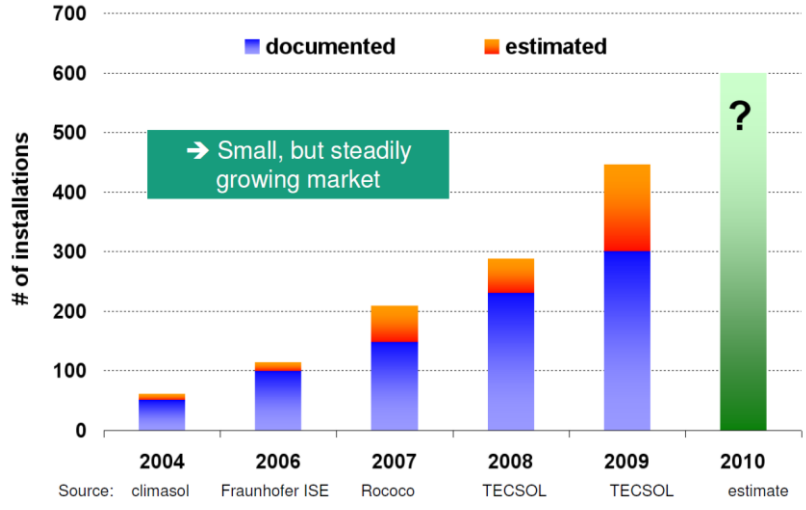
(Mouchot and Weber 1987)

Current state of deployment



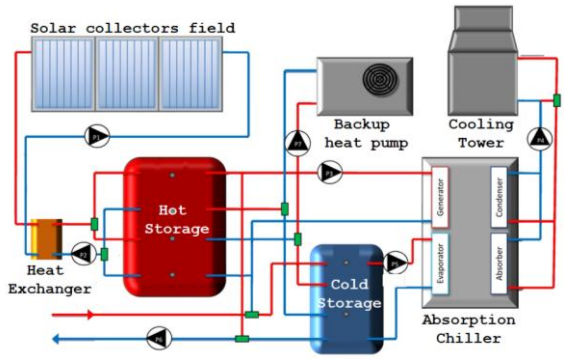
(Langniß et al., 2007)

Market- about 1000 systems in 2011



Examples of installaion

Examples
1. Single effect chiller for air-conditioning



Solar cooling

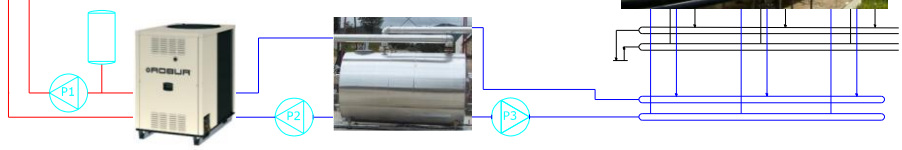
Examples
2. Single effect chiller for refrigeration

Solar cooling

Fresnel Collector

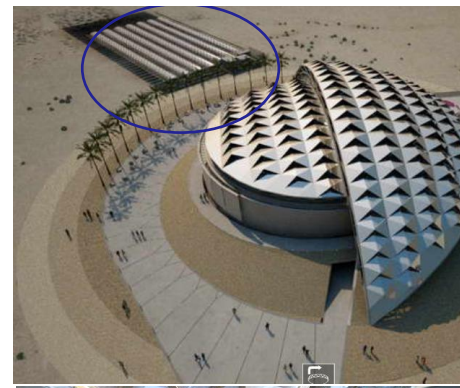
Cooling load:
Fermenters

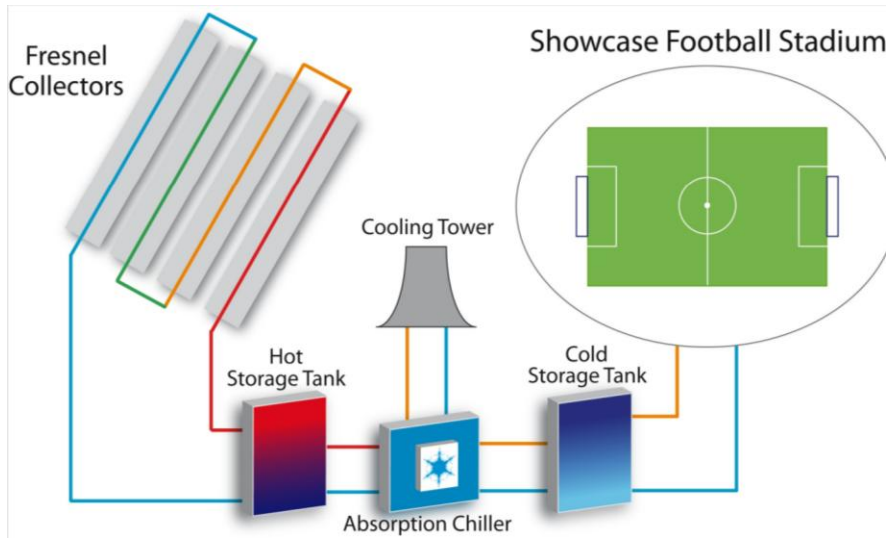
Cold Storage



Absorption Chiller

Double effect chiller for air-conditioning




Fresnel
Collectors
Showcase Football Stadium
Cooling Tower
Hot
Storage Tank
Cold
Storage Tank
Absorption Chiller

Industrial Solar Fresnel Collector Field

- 4 collector strings with 16 modules each
- Total aperture area 1408 m^2
- Gross area approx. 2100 m^2
- Pressurized water circuit at 16 bar
- 2 U-loops
- U-loops are connected in reverse-return system

Thermax chiller
Cooling capacity 750 kW
Max COP 1,39 (LiBr-H2O, 2 effect)
Integrated backup-burner
Dimensions (l/w/h) 4/2.2/2.7 m
Operating weight 8.1 tons

Thanks for your attention