Simulation and analysis of solar subcooled absorption-compression hybrid cooling system

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Outline

- Introduction
- Model
- Results and discussion
- Conclusion
- Prospect

1. Introduction

- Solar absorption chiller is easy to be commercially applicable
- Its cooling capacity usually depends on the aperture area of collector
- The collector installing at the facade of building works inefficiently, so that the collector should be only installed at the roof of building

1. Introduction

- Except for some small buildings, the total area of commercial building is larger than the area of roof
- The auxiliary energy is essential in the solar absorption cooling system to satisfy the cooling load
- The usual auxiliary energy is thermal energy and electric energy

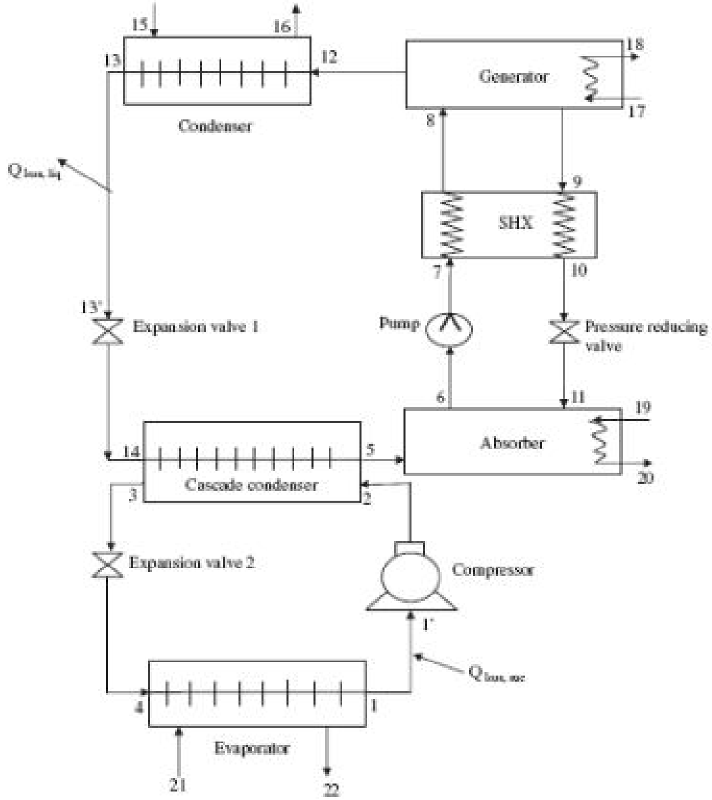
1. Introduction

- The system assisted by thermal energy is not feasible due to the expensive working cost
- To develop the solar absorption chiller which is economical and can satisfy the cooling load with the insufficient solar irradiance is important and urgent
- The system assisted by electric energy (solar absorption compression hybrid cooling system) can deal with it better

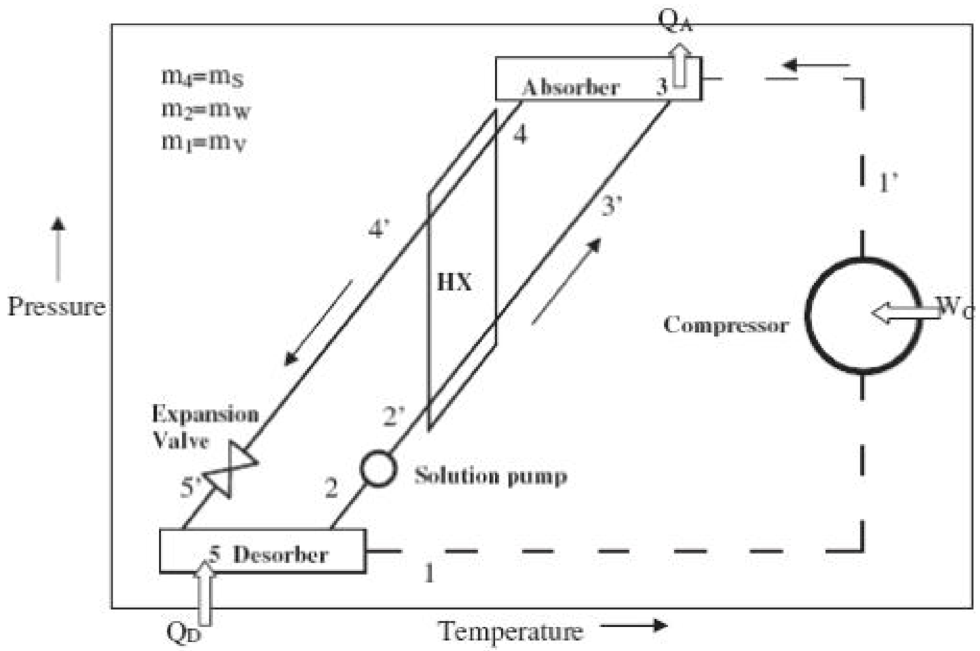
1. Introduction

- Five type absorption-compression hybrid cooling systems
  - First: based on the cascade cycle
  - Second: based on the vapor compression cycle with solution circuit (VCCSC)
  - Third: compressor connecting between the absorber and evaporator
  - Fourth: discharge gas of compressor to heat the generator
  - Fifth: some new systems

1. Introduction

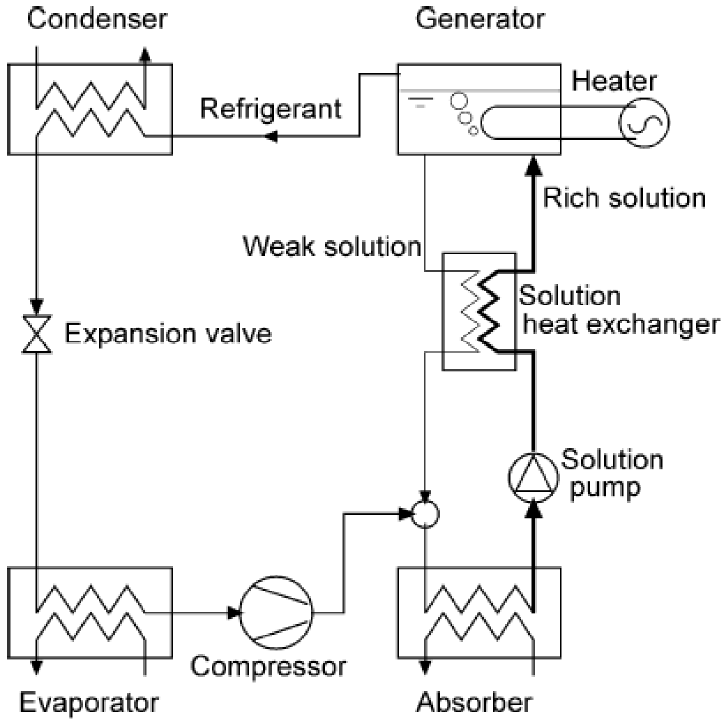


First



Second

1. Introduction



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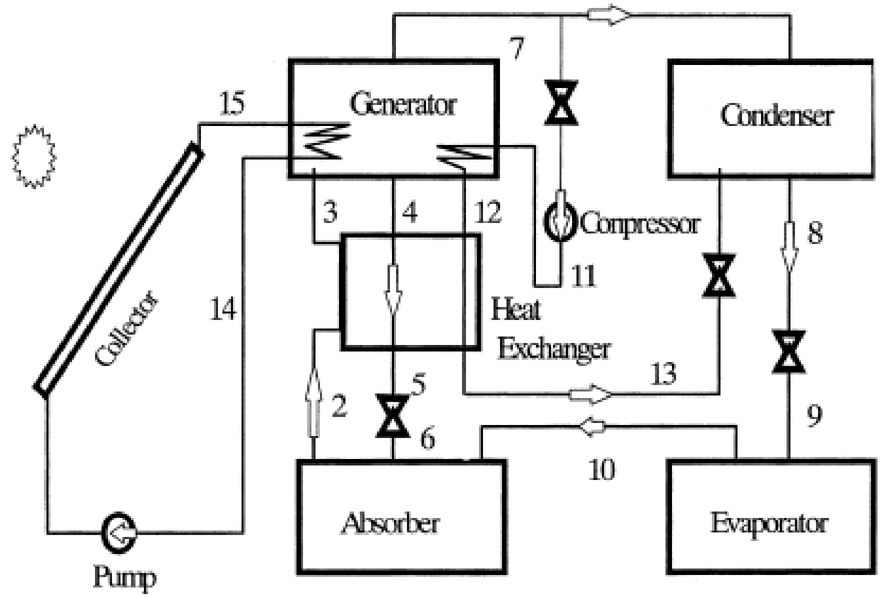


Fourth

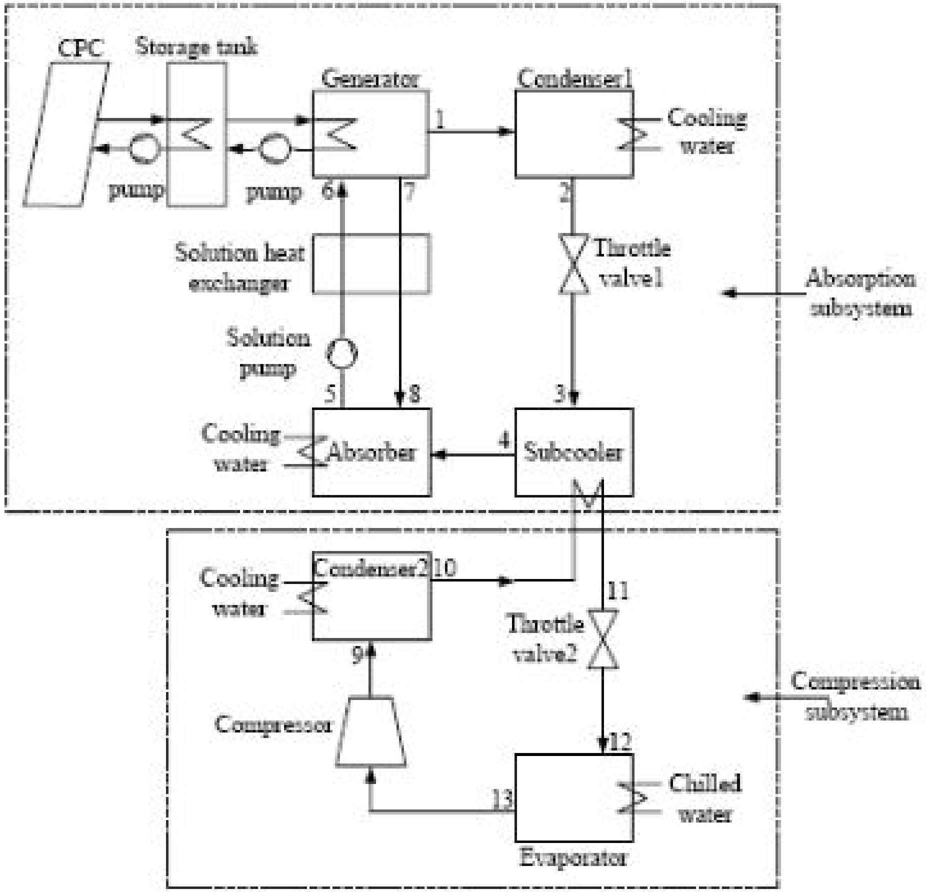
1. Introduction

- Not all the hybrid systems is suitable to be used in solar LiBr/H_2O absorption-compression system
  - First and second: is unreliable when the solar irradiance is insufficient
  - Third: compressor is very huge
  - Fourth: poor performance of compressor since its suction temperature is very high
- Subcooled absorption compression cycle (Chen GM)

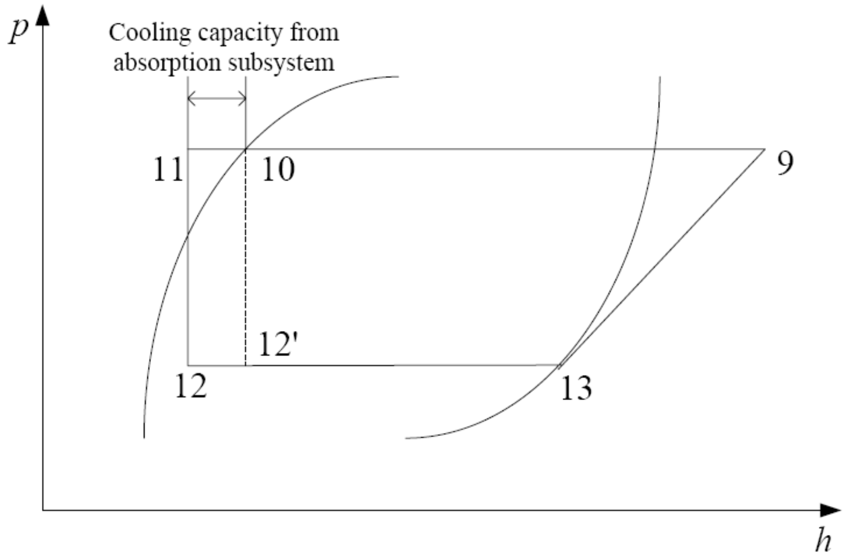
1. Introduction

- The solar subcooled absorption-compression hybrid cooling system (SACHCS) is better and efficient
  - Construction is not complicated
  - Always satisfies the cooling load regardless of solar irradiance
  - Evaporator temperature of absorption subsystem is higher
  - Wider working range of generator temperature
  - Subcooled compression

1. Introduction



SSACHCS



Cycle principle

1. Introduction

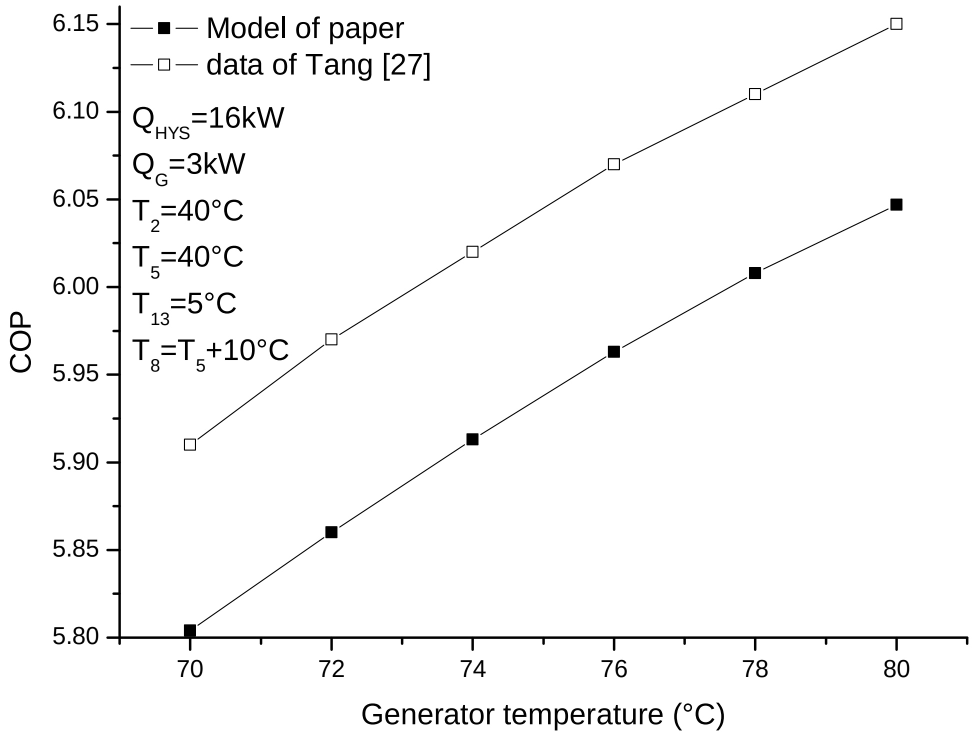
- The variation of working characteristic of absorption subsystem does not have significant effect on the working characteristic of compression subsystem
- The low grade cooling capacity of absorption subsystem transform into the high grade one without extra work by the throttling valve

1. Introduction

- The generator temperature is not stable and depends on the system parameter
- Once the system parameter can not match each other, too higher or too lower generator temperature deteriorates the performance and reliability seriously
- Objective: analyzes the variation of performance with the system parameter

2. Model

- Parametric model
- Mass and energy conservation
- quasi-static
- the component is adiabatic except the collector
- Time step is 2min
- Maximum deviation is 1.8%



Validation

2. Model

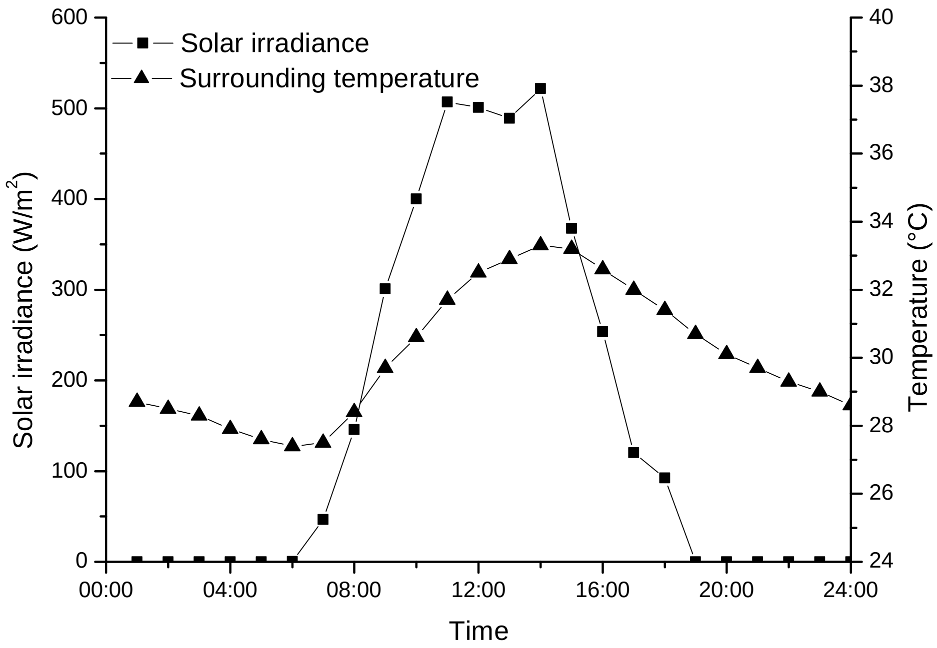
- The system parameter is based on a typical commercial building of which cooling load is 240kW, number of floor is 5, area of floor is 384m^2 and so on

System parameter

Parameter	Value
Number of CPC	54
Aperture area of single CPC (m^2)	3
Volume of single CPC (m^3)	2.4×10^{-3}
Volume of storage tank (m^3)	1.7
Initial T_D (° C)	35
Inlet temperature of cooling water (° C)	32
Outlet temperature of chilled water (° C)	5
Cooling capacity of absorption subsystem (kW)	17
Cooling capacity of hybrid system (kW)	240
Effectiveness of SHX ε	0.7
Isentropic efficiency of compressor η_s	0.8
Mechanical efficiency of compressor η_m	0.9

2. Model

- Typical solar irradiance and outdoor temperature of August in Guangzhou



Meteorological data in simulation

2. Model

- Three indexes of performance
  - Mean COP

$$\overline{COP}_{HYS} = \frac{1}{n}\sum_{i=1}^{n} COP_{HYS}$$

  - Working time fraction of absorption subsystem (WTF)

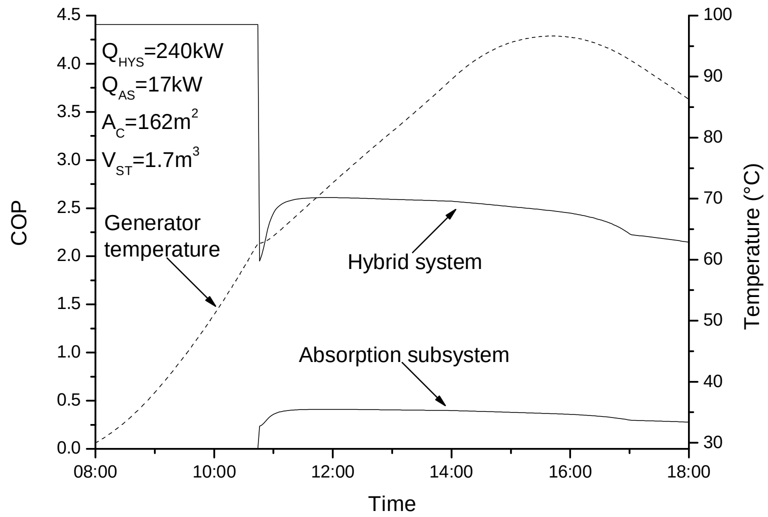
$$\lambda = t_{AS} / t_{HYS}$$

  - Energy saving fraction of hybrid system (ESF) (key)

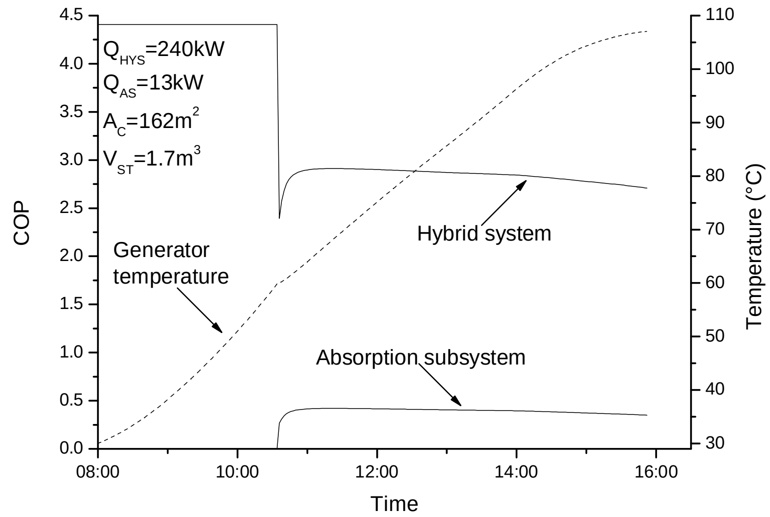
$$\psi = \lambda \cdot \frac{Q_{AS}}{Q_{HYS}} \times 100\%$$

3. Results and discussion

- Working process with different Q_{AS}



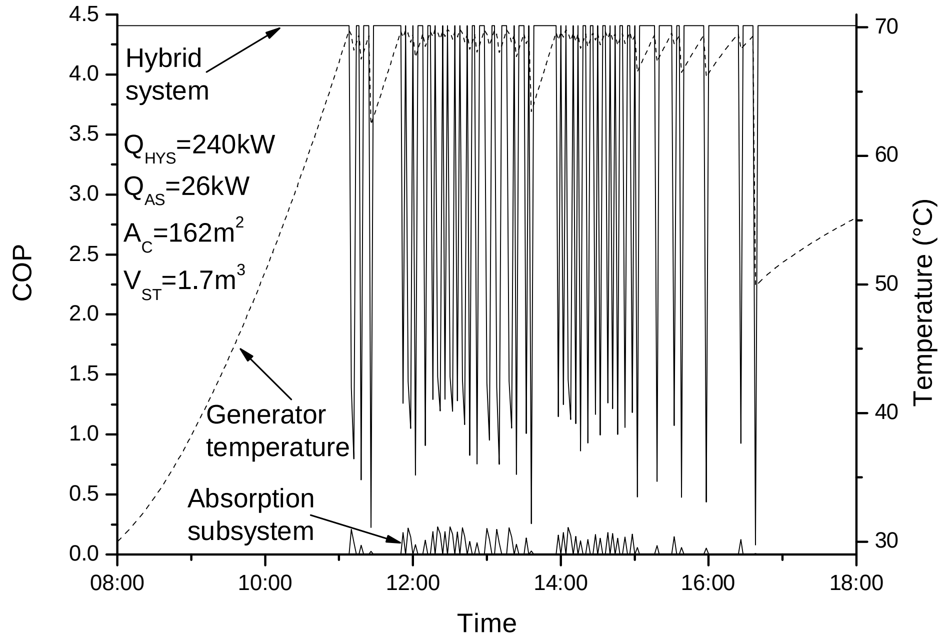
Q_{AS}=17kW



Q_{AS}=13kW

3. Results and discussion

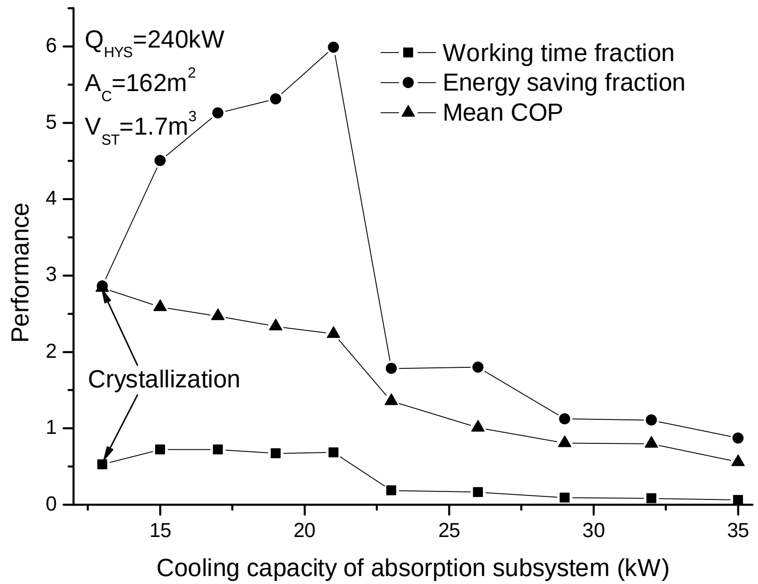
- Working process with different Q_{AS}
- Too low Q_{AS} leads to crystallization
- Too high Q_{AS} results in the oscillation of COP and generator temperature, shortens the time of absorption subsystem



Q_{AS}=26kW

3. Results and discussion

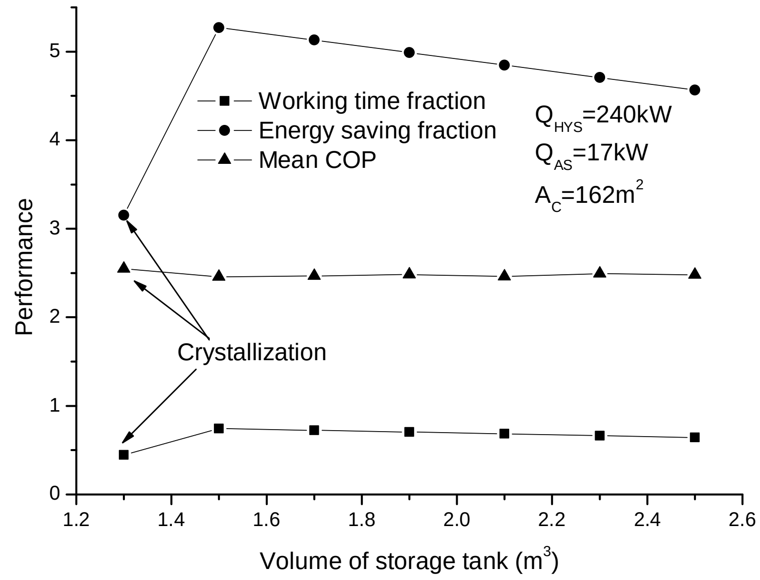
- Too low or too high Q_{AS} is harmful to the system performance
- The maximum ESF is 5.98% when the Q_{AS} is 21kW



Performance with Q_{AS}

3. Results and discussion

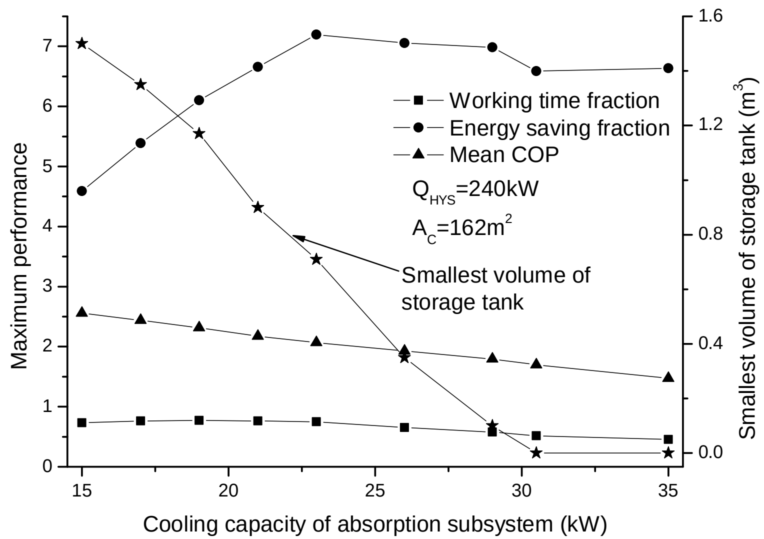
- The decrease of V_{ST} can improve the ESF by the increase of working time of absorption subsystem
- Too low V_{ST} also makes crystallization



Performance with V_{ST}

3. Results and discussion

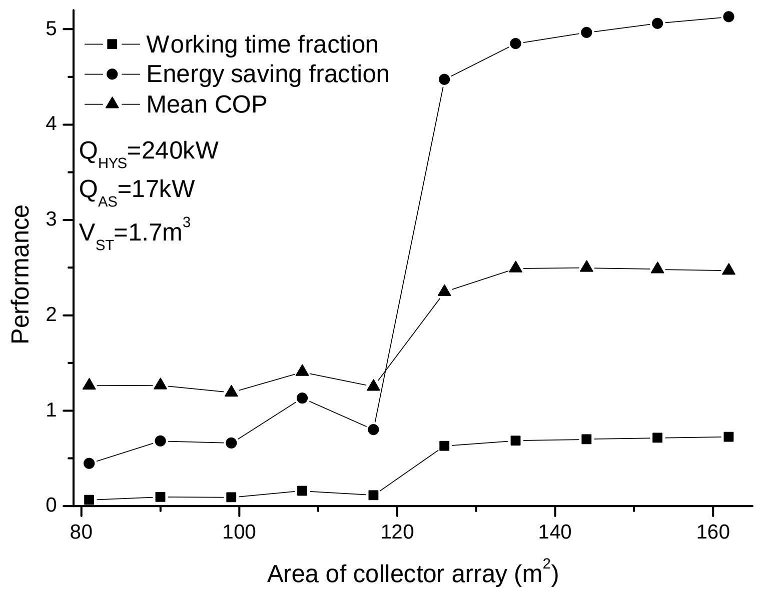
- By the appropriate change of V_{ST}, the maximum ESF goes up to 7.2%
- The corresponding Q_{AS} is 23kW



Maximum performance

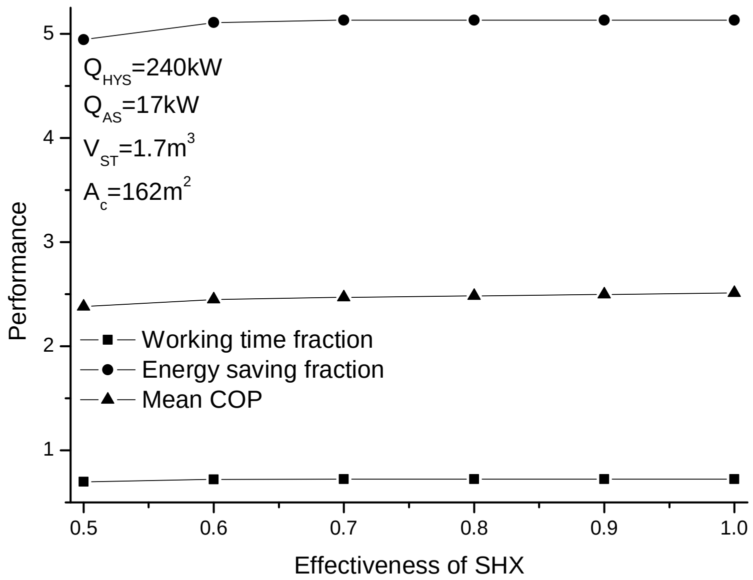
3. Results and discussion

- The performance goes down significantly as the A_C is less than $126m^2$
- When the A_C exceeds to $126m^2$, the performance only rises slightly with the increase of A_C

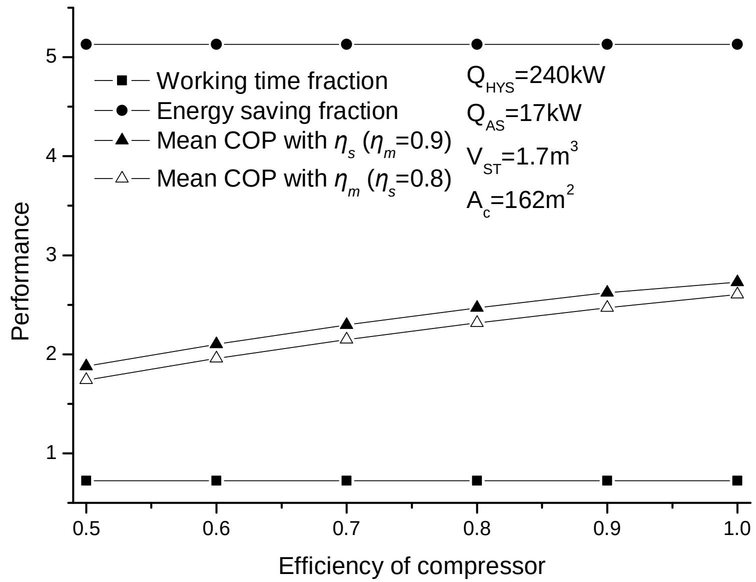


Performance with A_C

3. Results and discussion



Performance with effectiveness of SHX

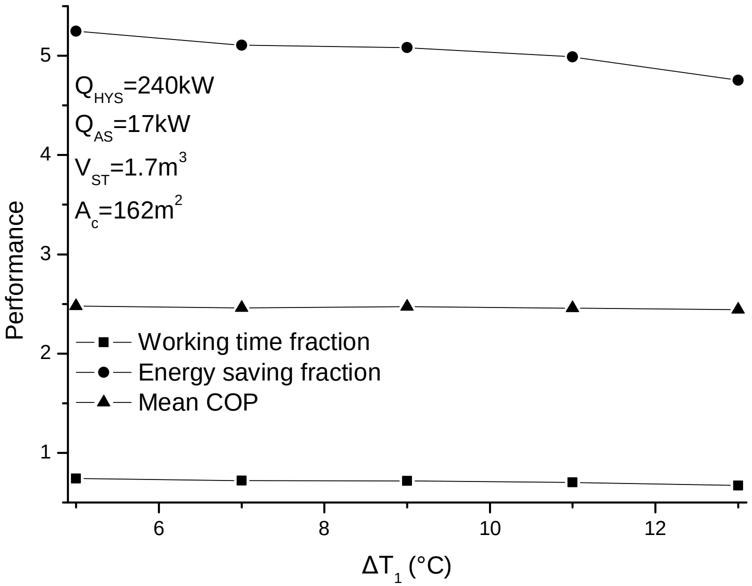


Performance with efficiency of compressor

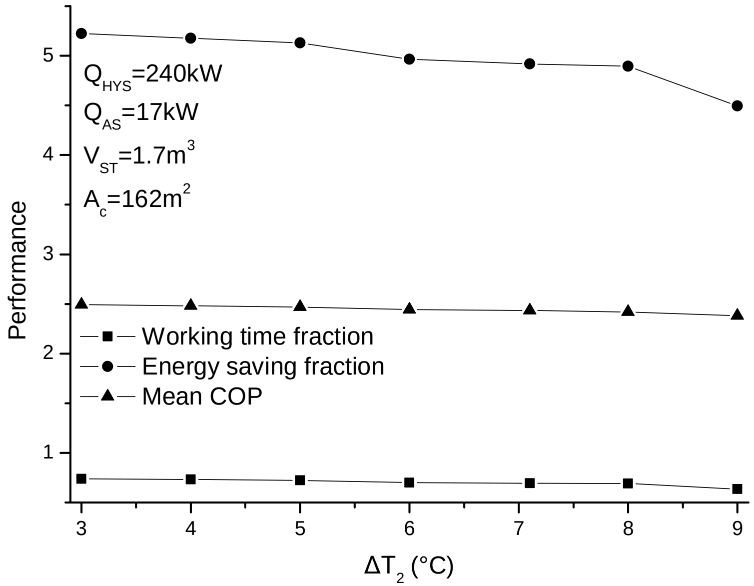
3. Results and discussion

ΔT_1 denotes the temperature drop of storage tank and generator

ΔT_2 denotes the temperature drop of outlet refrigerant of compression subsystem and subcooler



Performance with ΔT_1



Performance with ΔT_2

4. Conclusion

- The efficient working condition of SSACHCS matches the feature of cooling load of office and commercial building
  - The Q_{AS} is not required to be too high to increase the system performance
  - Not all the space of roof is required to install the collector so that the collector can be mounted more flexibly in the roof

4. Conclusion

- The WTF and mean COP go down with the increase of Q_{AS}. The performance drops significantly due to the repeated start and stop as well as the long stop of absorption subsystem as the Q_{AS} is greater than 21kW. But the crystallization happens as the Q_{AS} decreases to 13kW. The optimal Q_{AS} that maximizes the ESF is 21kW. The corresponding maximum ESF is near 6%.

4. Conclusion

- The COP and the crystallization risk of absorption subsystem all go up with the decrease of V_{ST}. Especially, the decrease of V_{ST} can improve the performance evidently as the Q_{AS} is higher than 21kW. The maximum ESF is 7.2% when Q_{AS} and V_{ST} are 23kW and 0.71m^3, respectively.

4. Conclusion

- The system performance gains significant improvement as the A_C is larger than $126m^2$. But the system performance just rises slowly when the A_C increases from 126 to $162m^2$.

4. Conclusion

- The performance goes up slightly with the improvement of effectiveness of SHX when the effectiveness of SHX exceeds to 0.6. The variation of efficiency of compressor only changes the mean COP. The performance goes down with the increase of ΔT_1 and ΔT_2. And both effect on the ESF is somewhat higher than that of effectiveness of SHX.

5. Prospect

- Improvement of working process model
- Design principle of system based on the meteorological data in the period of cooling supply (April to October)
- Appropriate control based on the variation of cooling load
- Prototype development and experiment

Thank you for your attention！