



SJTU-NTNU JRC



Status and Plans for Research Group for Refrigeration, LNG and Heat pump systems

Prof. Trygve M. Eikevik - Prof. Guoliang Ding

Jan. 23rd 2015



Participants from SJTU

- Prof. Guoliang Ding
- Prof. Yonglin Ju
- Prof. Wensheng Lin
- Dr. Haitao Hu
- PhD-stud Yifei Yang
- PhD-stud Xiaojun Xiong
- Master Jingjing Ye
- Master stud Jianrui Li

Participants from NTNU

- Prof. Trygve Eikevik
- Prof. Arne Bredeesen
- Dr. Ignat Tolstorebrov
- PhD-stud Zhequan Jin
- PhD-stud Han Deng
- Ms. Debbie Koreman



Agenda for the meeting



1. Minutes from last workshop June 2014
2. Status of PhD-projects, presentations on special topics/papers
3. Plans for interaction: PhD student exchanges. Research stays (budgets are available)
4. Status and plans for joint publications
5. Status and plans for involvement of industrial partners
6. Status on development of research projects with financing from other sources (research council/industry)
7. Review of education plan: double degrees and Summer School activities 2015
8. Calendar for next meeting in Norway in 2015



2. presentations on special topics [8 PPTs]

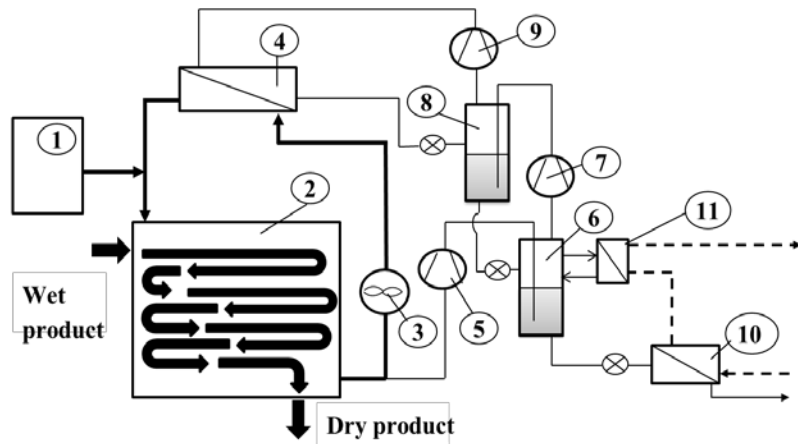


Time	Title	Name
10:15	Energy efficiency by vapor compression in superheated steam drying systems	Ignat Tolstorebrov Dr.
10:45	Performance analysis of solar assisted R744 ground source heat pump in different climates	Jingjing Ye Master
11:15	The requirements of standards for HC and CO2 systems	Ignat Tolstorebrov Dr.
13:30	Optimization of Natural Gas Pressurized Liquefaction Process with C3MR Refrigeration and CO2 Cryogenic Removal	Xiaojun Xiong PhD cand.
14:00	Energy performance of CO2 hybrid ground-coupled heat pumping system for hotel application	Zhequan Jin PhD-student
14:30	Simulation on falling film evaporation in coil-wound heat exchanger on LNG-FPSO	Jianrui Li Master student
15:20	Boiling and Condensation of Mixtures Considering Entrainment & Deposition of Droplets	Han Deng PhD student
15:50	Research on a CFD Model to Simulate Water Condensation in Fin-Tube Heat Exchanger under Dehumidifying Conditions	Yifei Yang PhD cand.
16:30	Lib visiting	Team work All the people

Energy efficiency by vapor compression in superheated steam drying systems

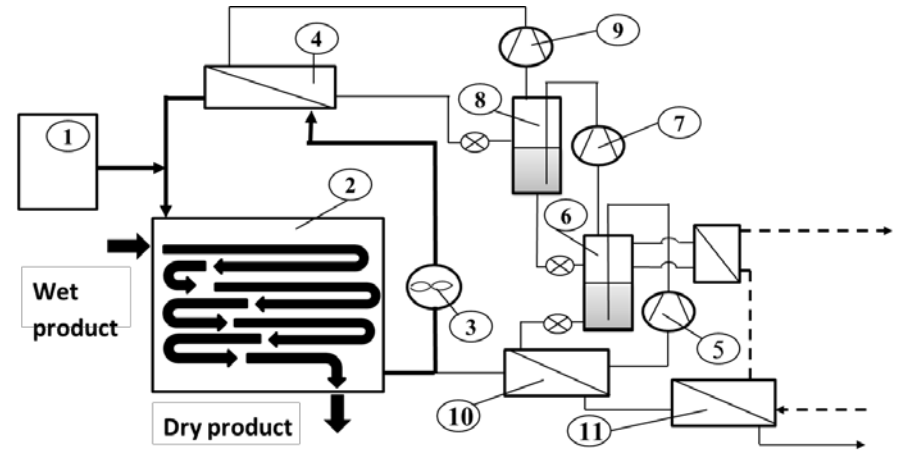


Discussion of possible solutions of R718 (H₂O) application as a refrigerant for processes, which requires excessive amount of energy. Two main schemes is observed: open and closed.



1. Steam generator; 2. Drying chamber; 3. Fan; 4. Heat exchanger; 5. Compressor low pressure; 6. First intermediate pressure vessel; 7. Compressor medium pressure; 8. Second intermediate pressure vessel; 9. Compressor high pressure; 10. Heat exchanger for hot tap water; 11. Extra heat exchanger.

— Main flow of steam; - - - Surplus steam flow; . . . Tap water



1. Steam generator; 2. Drying chamber; 3. Fan; 4. Heat exchanger; 5. Compressor low pressure; 6. First intermediate pressure vessel; 7. Compressor medium pressure; 8. Second intermediate pressure vessel; 9. Compressor high pressure; 10. Evaporator; 11. Hot tap water heat exchanger.

12 Extra heat exchanger
— Main flow of steam; - - - Surplus steam flow; . . . Tap water

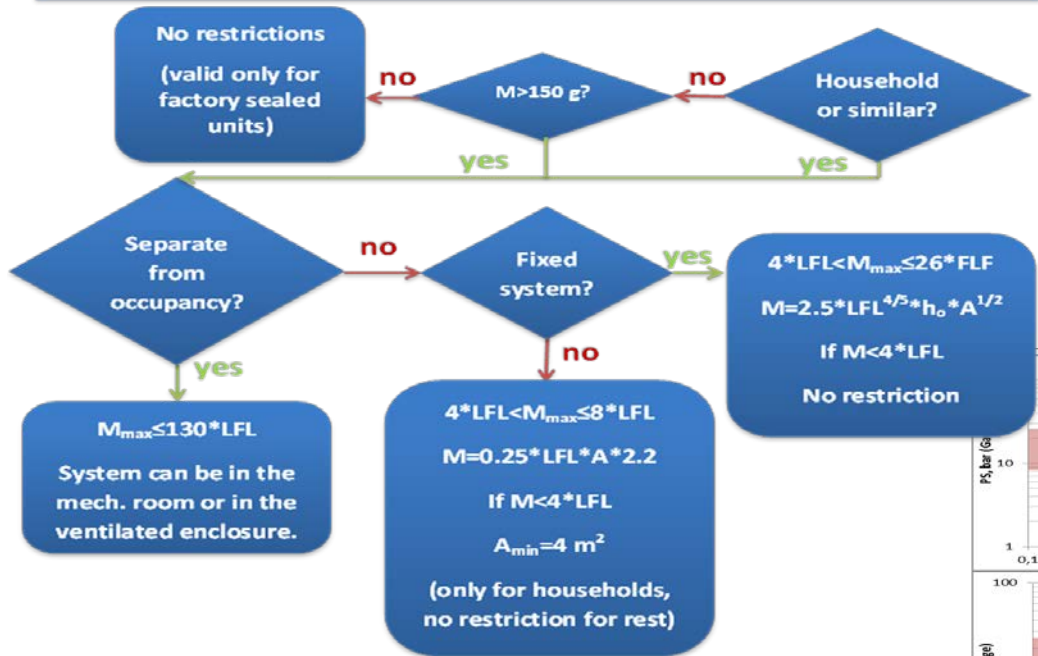
	Used energy, kW	Steam regeneration, kW	Water heating, kW	COP total, -	COP steam, -	DE, kWh kg ⁻¹
Energy source: Electricity						
Traditional scheme	1638.6	1556.6	1542.6	1.89	0.95	0.79
Open system	405.4	1556.6	371.0	4.75	3.84	0.19
Closed system	470.2	1556.6	406.5	4.17	3.31	0.22

Requirements of standards for refrigeration and HP system which operates with CO₂ and HC



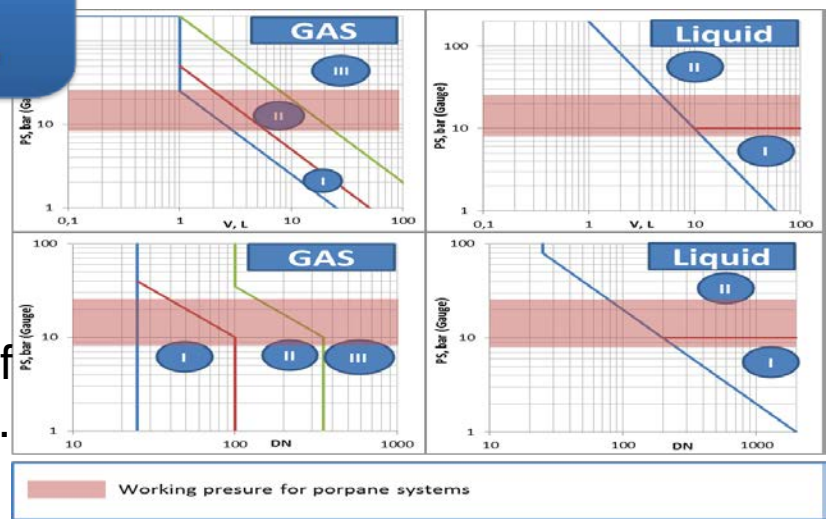
Review of safety requirements of different EU and ISO standards concerning application of Hydrocarbons and CO₂ systems for refrigeration, A/C and heat pumps for human comfort

Heat pumps for human comfort and air-conditioning systems



Requirement for ventilation and position of machinery room is observed

Pressure vessel requirements: strong limitations for HC refrigerants



Refrigerant charge requirements: function of room surface, volume and occupation class.

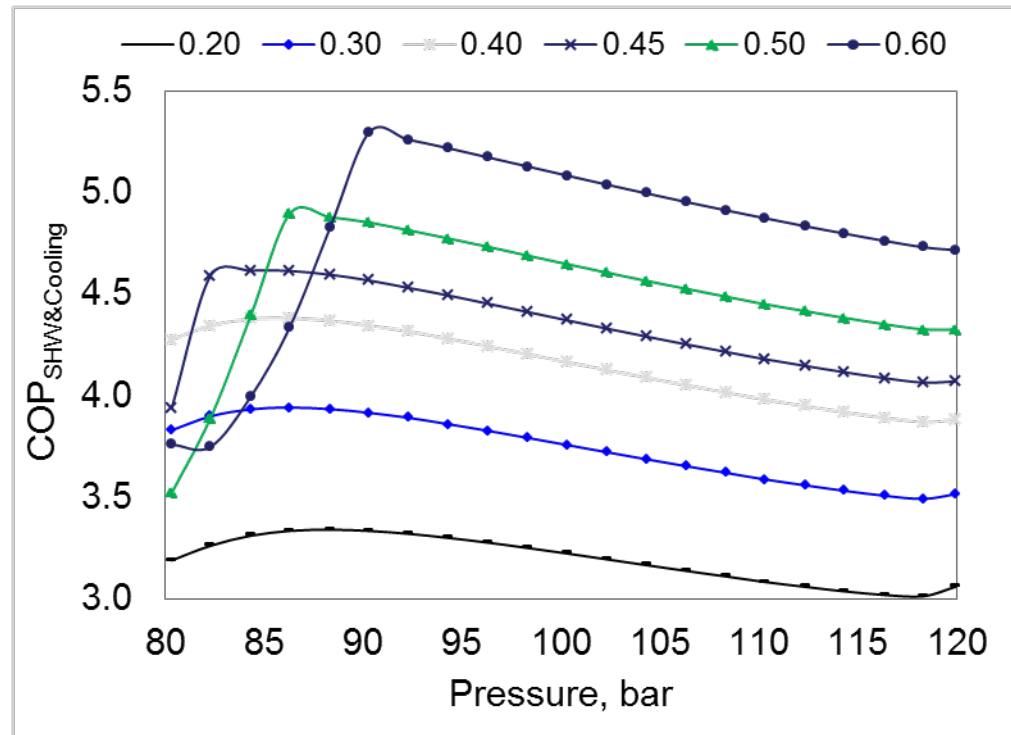
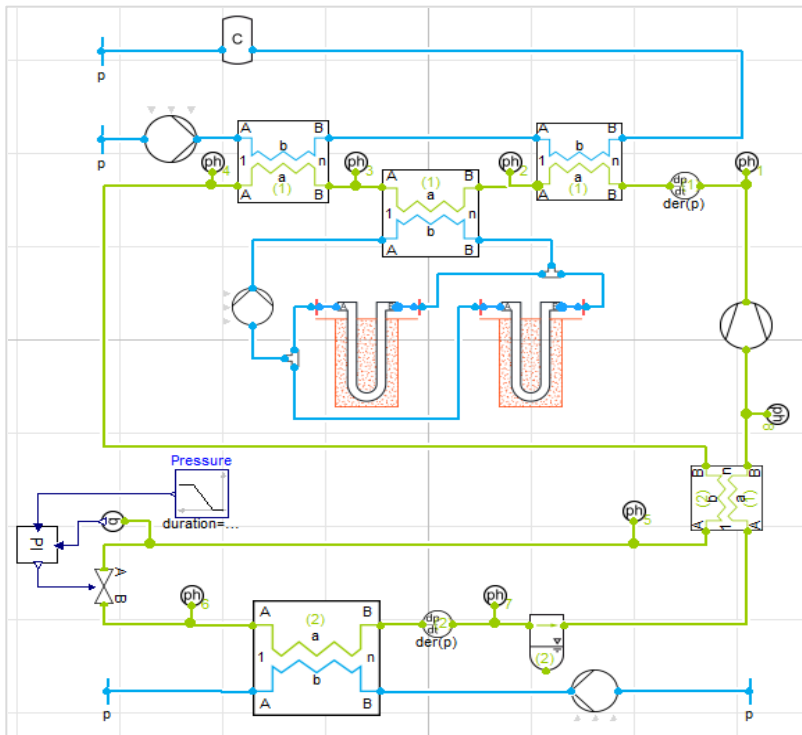


Supervisors: Prof. Trygve M. Eikevik, Prof. Petter Neksa, Dr. Armin Hafner

Title: Energy performance of CO₂ hybrid ground-coupled heat pumping system for hotel application

Main idea:

- Use 1 unit of the CO₂ system to cover Space Cooling and Hot water load or Space Heating and Hot water load for hotel

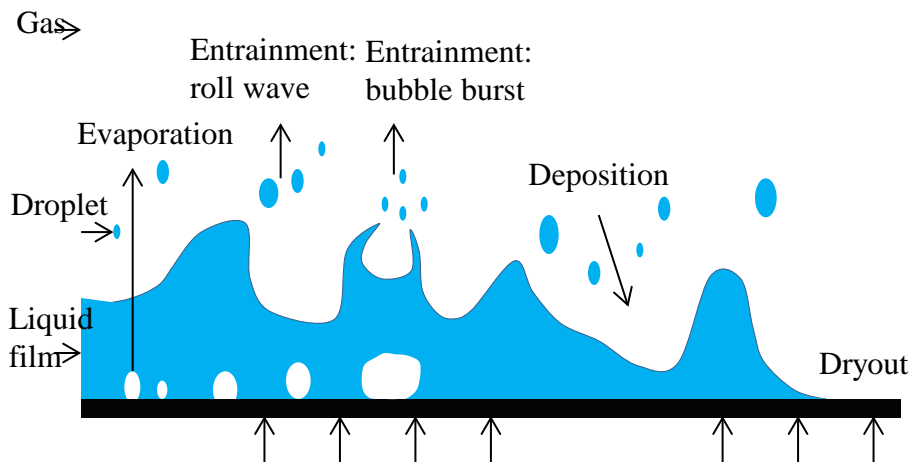




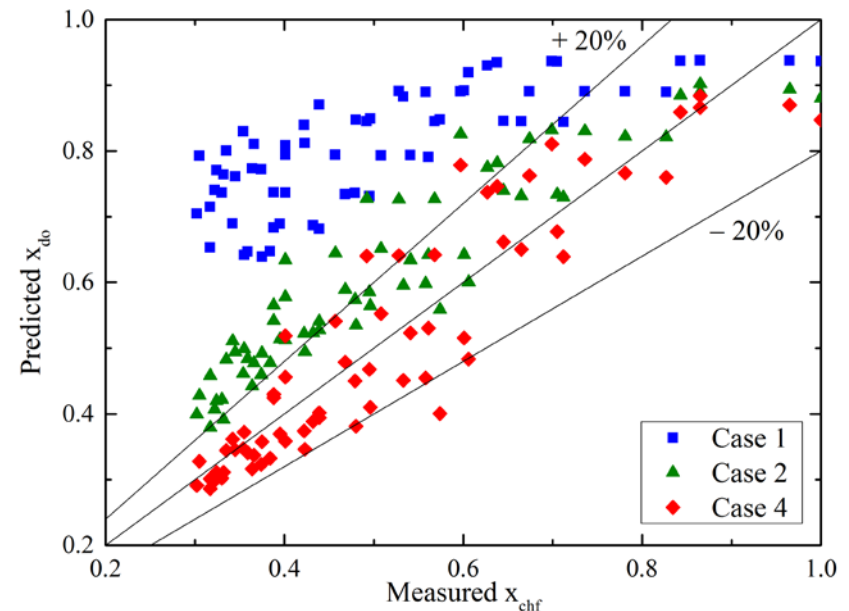
Supervisors: Prof. Maria Fernandino, Prof. Carlos A. Dorao

Title: Boiling and Condensation of Mixtures Considering Entrainment and Deposition of Droplets

Goal: Study the hydrodynamic non-equilibrium effects on the boiling and condensation of mixtures



Physical model of annular-mist flow for boiling of binary mixtures

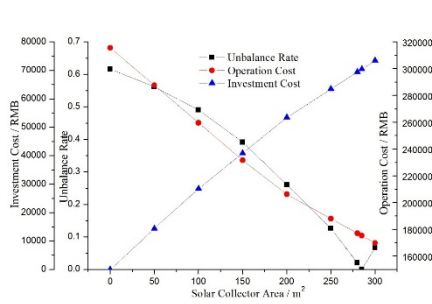


Prediction of the dryout quality and comparison with the experimental data

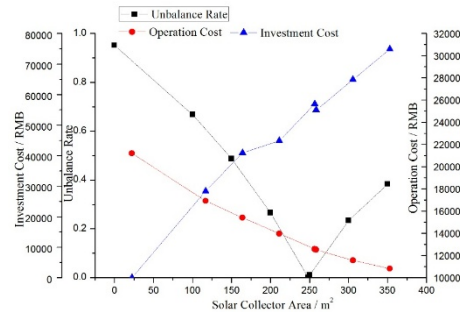
Performance Analysis of Solar Assisted R744 Ground Source Heat Pump in Different Climates— *Jingjing Ye, supervisor Prof. Guoliang Ding, Prof. Trygve Eikevik*

Main idea:

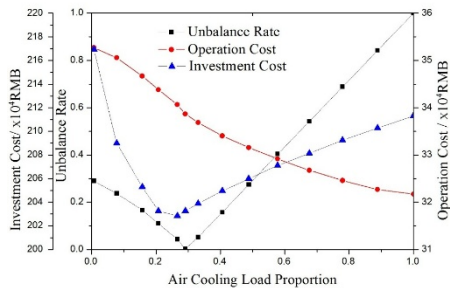
- Eliminate energy unbalance for R744 geothermal heat pump in difference climates
- simulate and analyze the performance of solar/air source gas cooler assisted GSHP



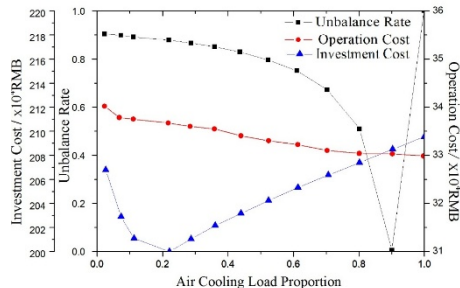
Harbin



Trondheim

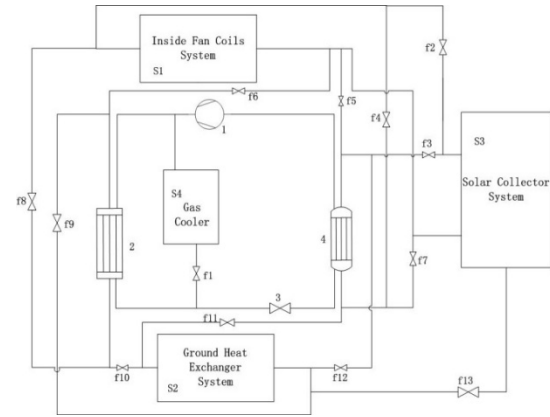


Shanghai



Guangzhou

Simulation results



System Design and Validation

- Status:
- Models and validation completed
 - Analysis completed
 - 1 conference paper, 2 Chinese paper published
 - 1 patent applying



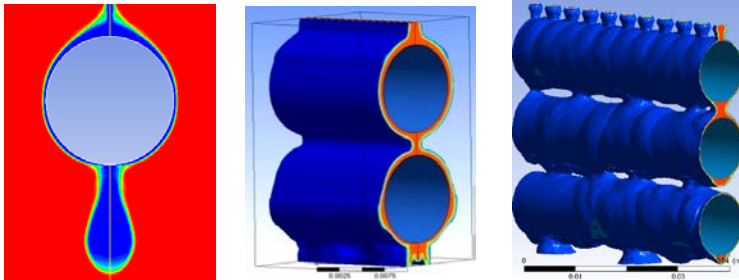
Simulation on falling film evaporation in coil-wound heat exchanger on LNG-FPSO—

Jianrui Li, supervisor Prof. Guoliang Ding

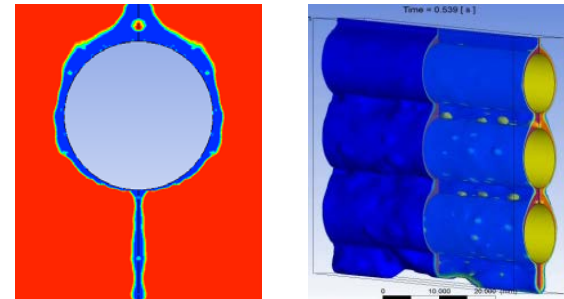
Main idea:

- Develop a verified CFD model for simulating the model of falling film evaporation in CWHE on LNG-FPSO
- Analyze Heat transfer performance of CWHE on offshore conditions

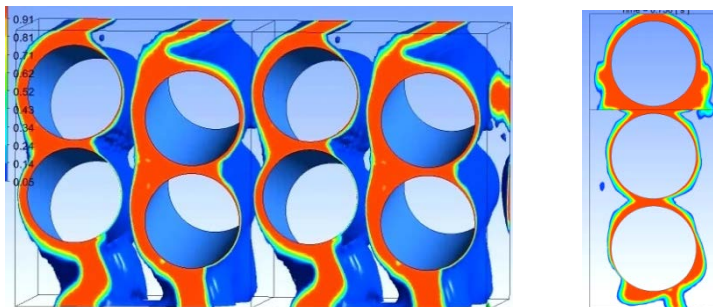
Simulation results



FLOW PATTERNS



EVAPORATION



OFFSHORE CONDITIONS

Status:

- Numerical models completed
- The result analysis in progress
- Experiments preparing
- Two or more papers preparing

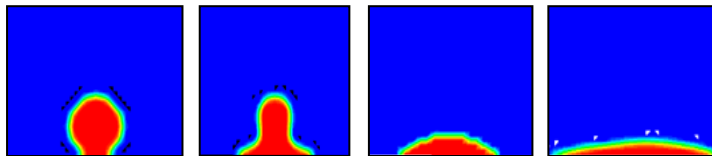


Research on a CFD Model to Simulate Water Condensation in Fin-Tube Heat Exchanger under Dehumidifying— *Yifei Yang, supervisor Prof. Guoliang Ding*

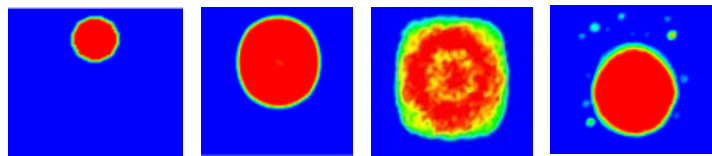
Main idea:

- Develop a validated CFD model for simulating water film condensation
- Compare the performance between water film and water droplets condensation

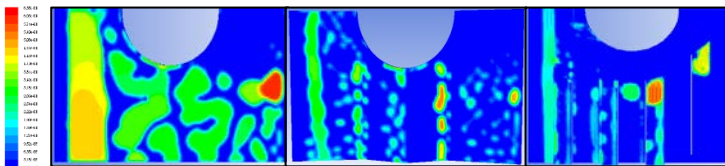
Water film spreads



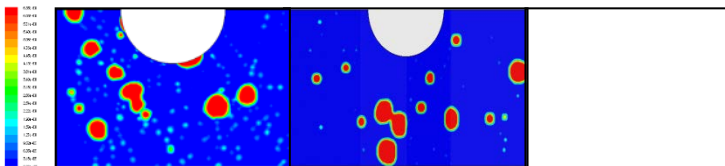
Water film slips



Water films condense



Water droplets condense

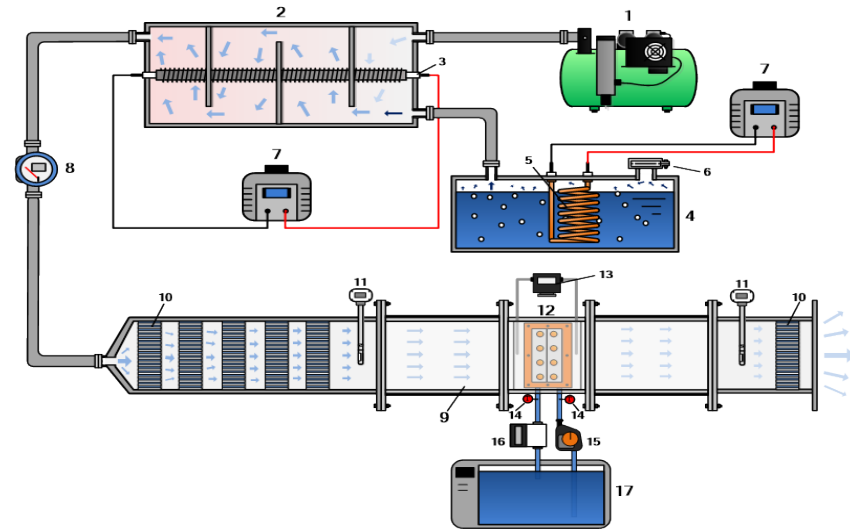


Plain fin

Wavy fin

Slit fin

Simulation results



Experimental schematic diagram

Conclusions:

- Establish water film condensation
- CFD simulation results
- Experimental validation



3. Plans for interaction: PhD student exchanges. Research stays (budgets are available)



1) From Norway

- Zhequan Jin plan to visit SJTU in 2015
- Han Deng plan to visit SJTU in 2015

2) From China

- Chao Ding plan to visit NTNU in 2015



4. Status and plans for joint publications



Seven papers published

1. H.Hu, T.M.Eikevik, P.Neksa, A.Hafner, Q. Huang, J.Ye; *Performance and economy analysis of a R744 heat pump system with an ambient air-cooled gas cooler and a ground heat exchanger to avoid unbalance of traditional ground source systems under different climatic conditions*. Proceedings of XV European Conference "The latest technology in air conditioning and refrigeration industry", June 7-8, 2013, Milano, Italy.
2. H.Hu, T.M.Eikevik, P.Neksa, A.Hafner, D.Zhuang; *Parametric study on the performance of vertical ground source U-tube heat exchanger with long tube length*. Proceedings of XV European Conference "The latest technology in air conditioning and refrigeration industry", June 7-8, 2013, Milano, Italy.
3. J.YE, T.M.Eikevik, P.Nekså, A.Hafner, G.Ding, H.Hu; *Performance and Economy Analysis of a Solar Assisted CO2 Ground Source Heat Pump with Air-Cooled Gas Cooler under Different Climate Conditions*, 11th IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
4. G. Zhao, T.M. Eikevik, Y.Li, T.Andersen, Y.Ladam; *Solar Driven Power Production using CO2 as Working Fluids* 11th IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
5. J.Xiong. R.Wang, T.M.Eikevik; *Use of ejectors to increase the energy efficiency of heat pump and refrigeration systems*, 11th IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
6. Z.Jin, T.M.Eikevik, P.Nekså, A.Hafner, G.Ding, H.Hu; *Transient simulation of r744 hybrid ground coupled heat pump with modelica*, 11th IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
7. H.T.Andresen, Y.Li; *Modeling the heating of the Green Energy Lab in Shanghai by the geothermal heat pump combined with the solar thermal energy and ground energy storage*.



4. Status and plans for joint publications



Four Accepted papers in Chinese Journal of Refrigeration

1. Jie Xiong¹, Ruzhu Wang^{*1}, Trygve Magne Eikevik. A calculation model for mass entrainment ratio of single-phase R744 ejector cycle and experimental validation. Chinese Journal of Refrigeration. **Accepted.**
2. Geping Zhao, Yong Li, Trygve. Eikevik. Experimental Study of Low Temperature Driven Rankine Cycle Power Generation Using CO₂ as Working Fluid. Chinese Journal of Refrigeration. **Accepted.**
3. J. Ye, H. Hu, G. Ding, T.M. Eikevik. Performance analysis of a solar assisted CO₂ ground source heat pump. Chinese Journal of Refrigeration. **Accepted.**
4. J. Ye, H. Hu, T.M. Eikevik, G. Ding. Performance analysis of air source gas cooler assisted CO₂ ground source heat pump. Chinese Journal of Refrigeration. **Accepted.**

1 Chinese patent

H. Hu, J. Ye, G. Ding, T.M. Eikevik. Multi-source assisted R744 ground source heat pump system. **Submitted.**



4. Status and plans for joint publications



1 Submitted papers

1. H.Hu, T.M.Eikevik, P.Neksa, A.Hafner, G.Ding, Q.Huang, J.Ye; *Performance analysis of a R744 ground source heat pump system with air-cooled and water-cooled gas coolers, (Submitted to Journal of IJR).*

6 Proposed papers for the conference

1. Per Kjellsen, Trygve Magne Eikevik, Yanjun Dai, Solar-Assisted Heat Pump with PV-T Components, *Papers for IIR Congress in Yokohama, Japan*
2. Dan-Herman Thue, Guoliang Ding, Trygve Magne Eikevik Simulation of falling film flow patterns in CWHE on LNG-FPSO, *Papers for IIR Congress in Yokohama, Japan*
3. Zhequan Jin, Trygve M. Eikevik, Petter Neksa, Armin Hafner, Guoliang Ding, Haitao Hu; Energy performance of CO₂ hybrid ground-coupled heat pumping system for hotel application, *Papers for IIR Congress in Yokohama, Japan*
4. *Other 2 conference papers.*

1 Planning paper about R717:

1. Trygve Magne Eikevik, et al. Application of R717 in Norway. Chinese Journal of Refrigeration. **(Invited paper)**



5. Status and plans for involvement of industrial partners



- SJTU- International Copper Association- Hisense Kelon (**China National Offshore Oil Corporation**)
- NTNU will during the autumn discuss with Norwegian companies like; Cadiao AS, Kuldeteknisk AS



6. Status on development of research projects with financing from other sources (research council/industry)



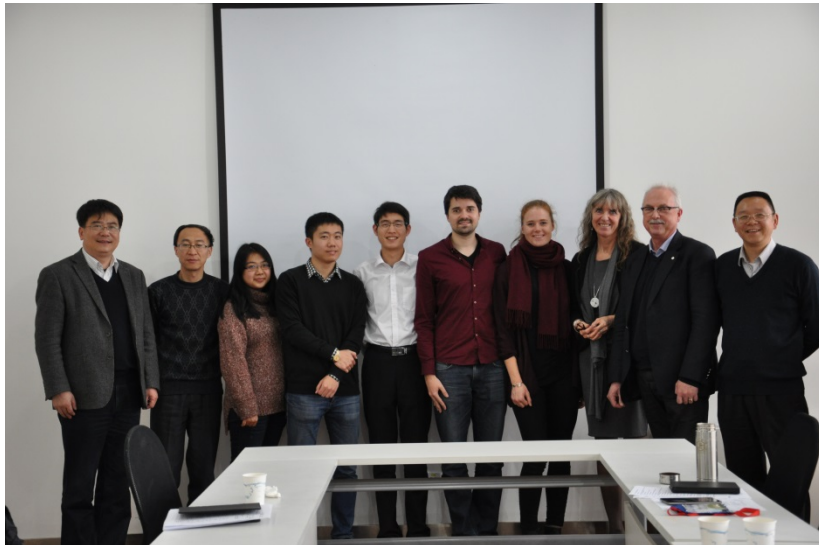
- The groups will be the partner **within JRC** to work in the coming period to apply for a research project within the **FME (Research center for Energy efficiency) in the Norwegian Research Council** with a deadline in November 2015 (draft in April).
- It will also be checked if it is possible to apply for Chinese funding, and to include some Chinese company into FME.



Double Degree Master students

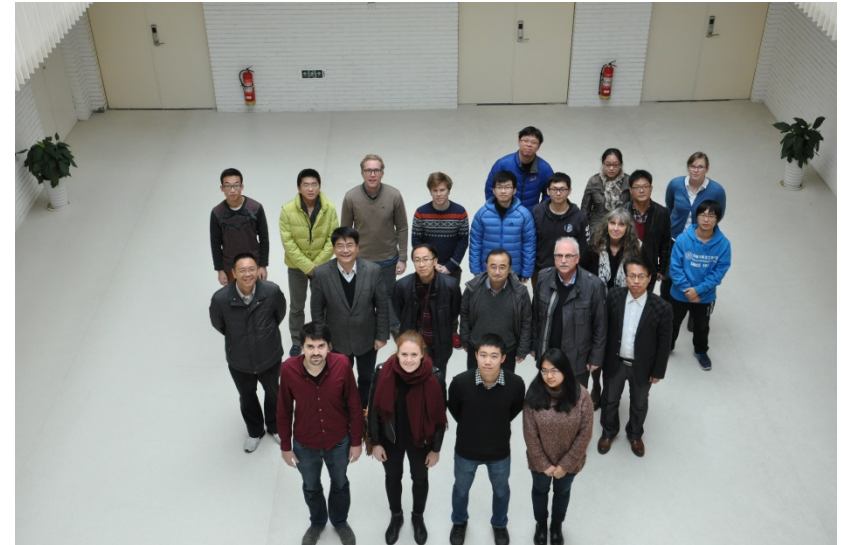
SJTU students 2013

- Weiqing Chen, Jie Xiong
- Jingjing Ye, Geping Zhao



NTNU students 2013

- Hanne Thorshaug Andresen
- Jacob Mann



DD Master graduation ceremony



Double Degree Master Thesis 2014

- **Hanne Thorshaug Andresen:** *Study on the performance of central solar heating plants with seasonal storage using underground soil in North China*, Supervisor: Prof. Yong Li, Co-supervisor: Prof. Trygve M. Eikevik
- **Jacob Aljoscha Mann:** *Experimental Investigation on Multi-stage Cryogenic Heat Pipe Heat Exchanger and its application in Small-scale LNG Processes*, Supervisor: Prof. Yonglin Ju, Co-supervisor: Prof. Trygve M. Eikevik
- **Weiqing Chen:** *Heat transfer and pressure drop for new natural working fluids*, Supervisor: Prof. Trygve M. Eikevik, Co-supervisor: Prof. Yonglin Ju
- **Jie Xiong:** Use of ejectors to increase the energy efficiency of heat pump and refrigeration systems, Supervisor: Prof. Trygve M. Eikevik, Co-supervisor: Prof. Ruzhu Wang
- **Jingjing Ye:** Solar assisted natural working fluids heat pump for Chinese buildings, Supervisor: Prof. Trygve M. Eikevik, Co-supervisor: Prof. Guoliang Ding
- **Geping Zhao:** Solar driven Power production using CO₂ as working fluid, Supervisor: Prof. Trygve M. Eikevik, Co-supervisor: Prof. Yong Li



Double Degree Master students

SJTU students 2014

- Jinrui Zhang

NTNU students 2014

- Per Kjellsen
- Erik Langaard Solberg
- Dan-Hermann Thue

SJTU students 2015

- 4 Students

NTNU students 2015

- Aim for 4 students



Summer School activities 2014/2015

- “*Heat Pumping Processes and Systems*”, 30 students, July 2014, Prof. Trygve M. Eikevik
- Plan: “Refrigeration and heat pumping processes and systems”, July 2015



8. Calendar for FME application of 2015



- There will be a «Video» meeting in end of Feb. 2015
 - for discussing the application for FME within the energy efficiency
- There will be a meeting in May 2015 for the detail of FME
- During the workshop in Norway (for the detail of FME)



Thanks for your attention.



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Joint Research Centre
In Sustainable Energy



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Norwegian University of
Science and Technology