



**SJTU-NTNU JRC**



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# **Status and Plans for CO<sub>2</sub> research group**

## **Natural Working Fluids**

**Prof. Trygve M. Eikevik - Prof. Guoliang Ding**

**June 27<sup>th</sup> 2014**



## Participants from SJTU

- Prof. Ruzhu Wang
- Prof. Guoliang Ding
- Dr. Haitao Hu
- PhD-stud Dawei Zhuang

## Participants from NTNU

- Prof. Trygve Eikevik
- Prof. Arne Bredeesen
- Prof. Maria Fernandino
- Prof. Petter Nekså
- Prof. Odilio Alves-Filho
- Dr. Ignat Tolstorebrov
- PhD-stud Zhequan Jin
- PhD-stud Han Deng
- Ing. Håvard Rekstad



# Agenda for the meeting



1. Minutes from last workshop November 2013
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 2<sup>nd</sup> part (autumn) of 2014 – Agreed dates for internet meetings
9. AOB



## 2. presentations on special topics



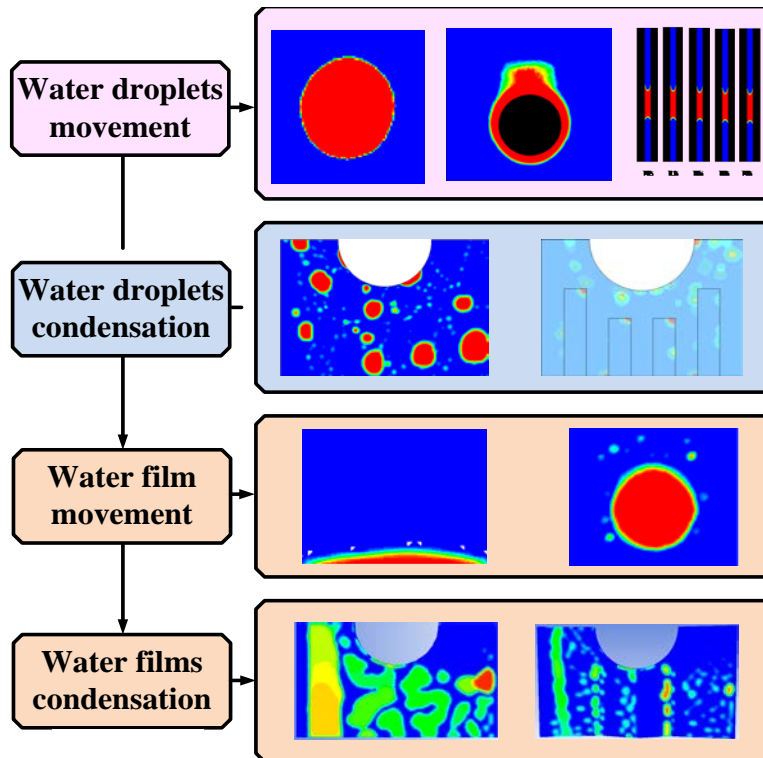
10:30	<b>R744 Refrigeration system configuration for supermarkets in warm climates</b>	Petter Nekså Prof.	A3
11:00	<b>Energy and Material Saving Technologies for Air Conditioners</b>	Guoliang Ding Prof.	A3
11:30-12:30	Lunch		Kjelhuset
12:30	<b>Heat transfer enhancement technology for refrigeration and heat pump systems</b>	Haitao Hu Dr.	A3
12:55	<b>CO<sub>2</sub> Refrigeration System for Chilling of Telephone Center – A Case Study</b>	Trygve M. Eikevik Prof.	A3
13:20	<b>Transient simulation of Hybrid R744 GCHP with Modelica</b>	Zhequang Jin PhD-student	A3
13:45	<b>Optimizing a CO<sub>2</sub> Heat Pump for Chilling of Ice Water and Heating of Hot Tap Water at 80°C</b>	Ignat Tolstorebrov Dr.	A3
14:10	Coffee break		A3
14:25	<b>Natural Refrigerants for cooling of Pelagic Fish in Fishing boats</b>	Håvard I. Rekstad Ing.	A3
14:50	<b>Simulation on falling film evaporation in spiral wound heat exchanger on LNG-FPSO</b>	Dawei Zhunang PhD-student	A3
15:15	<b>Condensation of mixtures under equilibrium and non-equilibrium conditions</b>	Han Deng PhD-student	A3



## Numerical model and experimental verification of water condensation in heat exchanger under dehumidifying conditions — *Dawei Zhuang, supervisor Prof. Guoliang Ding*

### Main idea:

- Develop a verified CFD model for simulating the water condensation
- Use CFD technique to evaluate HX performance under wet conditions



Simulation results



Experimental setup

### Status:

- Numerical models completed
- Experiments in progress
- One journal paper published (HVAC&R Research)
- Two or more papers preparing



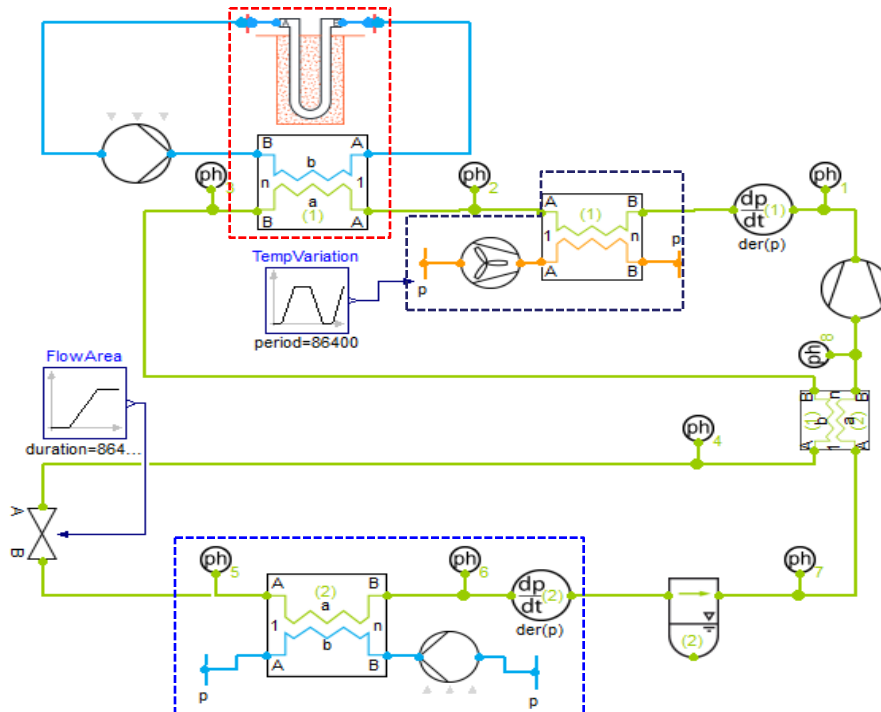
*Supervisors:* Prof. Trygve M. Eikevik, Prof. Petter Neksa, Dr. Armin Hafner

*Title:* **Transient simulation of Hybrid R744 GCHP with Modelica**

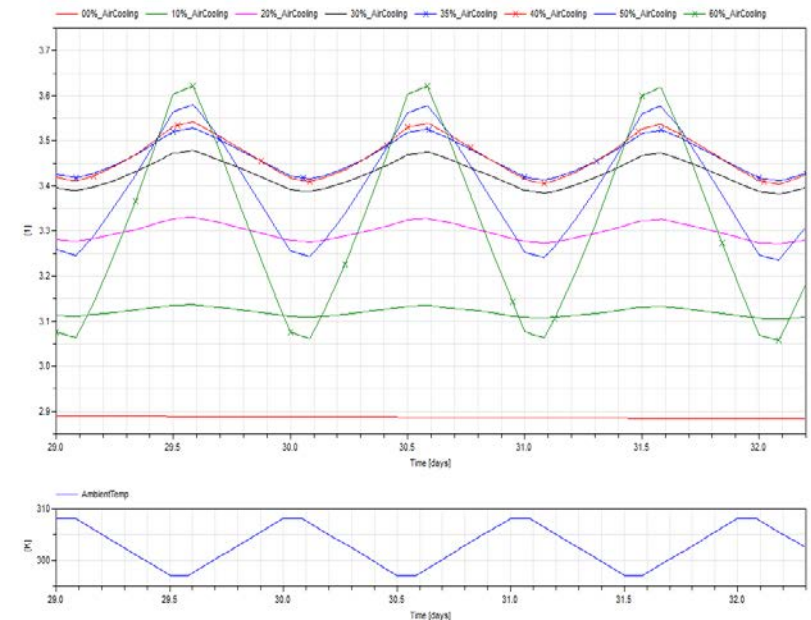
- Paper for 11<sup>th</sup> Gustav Lorentzen Conference 2014.

*Main idea:*

- Air-conditioning application of CO<sub>2</sub> as working fluid for GCHP
- System use ambient air & ground as heat sink (Hybrid GCHP)

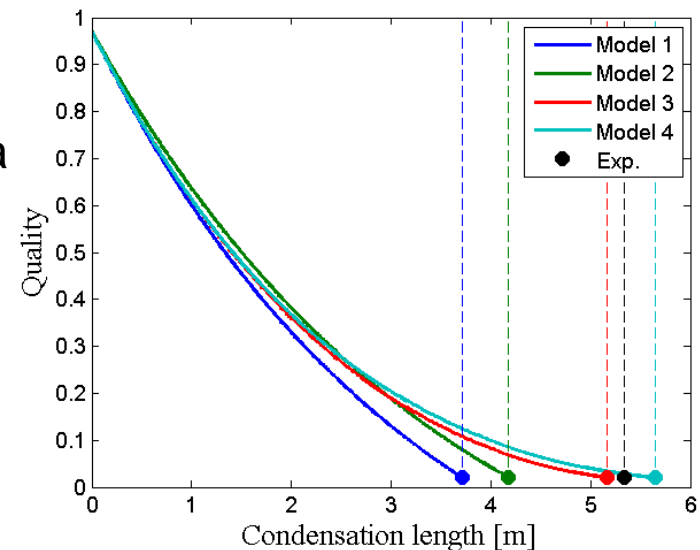
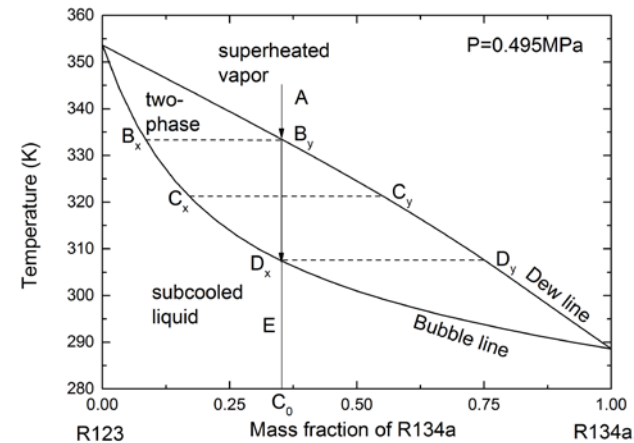
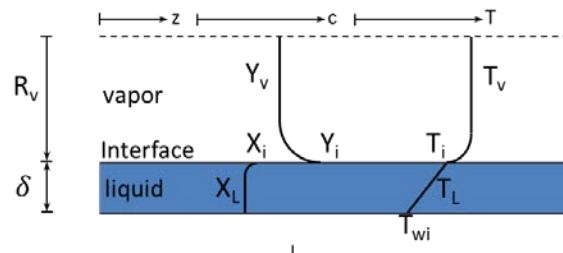


- One of simulation result:  
Optimal capacity of air-cooled gas cooler





- **Title:** Modeling of boiling and condensation of multicomponent mixtures for improved LNG processes
- **Supervisors:** Maria Fernandino, Carlos Dorao
- **Project status**
  - 1D model on boiling of near- and non-azeotropic mixtures
  - 1D model of condensation of mixtures (annular flow in pipes)
    - Equilibrium model and non-equilibrium model
    - Model validation with experimental data from literature





- **Next steps**

- Investigation of other non-equilibrium effects
- Annular mist flow (effect of entrainment & deposition)
- Possible stay in SJTU during 2015 – experimental work

- **Publications**

- Numerical Study on the Condensation Length of Binary Zeotropic Mixtures – *3<sup>rd</sup> Trondheim Gas Technology Conference, 4-5 June, Norway.*
- Simulation of Binary Mixtures Condensation Using Higher Order Methods, *Heat Transfer 2014, La Coruña, Spain.*
- A numerical investigation of flow boiling of near-azeotropic and non-azeotropic binary mixtures – *in preparation for journal publication*
- Numerical study of heat and mass transfer of binary mixtures condensation in minichannels – *submitted to Int. Comm. in Heat and Mass Transfer.*





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

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#### 1) From Norway

- Zhequan Jin may visit SJTU in 2015
- Han Deng may visit SJTU in 2015

#### 2) From China

- Chao Ding may visit NTNU in 2015



## 4. Status and plans for joint publications



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. 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 Energy and Buildings)*.
4. J.YE, T.M.Eikevik, P.Nekså, A.Hafner, G.Ding, H.Hu; *Performance and Economy Analysis of a Solar Assisted CO<sub>2</sub> Ground Source Heat Pump with Air-Cooled Gas Cooler under Different Climate Conditions*, 11<sup>th</sup> IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
5. G. Zhao, T.M. Eikevik, Y.Li, T.Andersen, Y.Ladam; *Solar Driven Power Production using CO<sub>2</sub> as Working Fluids* 11<sup>th</sup> IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
6. J.Xiong. R.Wang, T.M.Eikevik; *Use of ejectors to increase the energy efficiency of heat pump and refrigeration systems*, 11<sup>th</sup> IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
7. Z.Jin, T.M.Eikevik, P.Nekså, A.Hafner, G.Ding, H.Hu; *Transient simulation of r744 hybrid ground coupled heat pump with modelica*, 11<sup>th</sup> IIR Gustav Lorentzen Conference on Natural Working Fluids, September 2014, Hangshou, China
8. H.T.Andresena, 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*



## 5. Status and plans for involvement of industrial partners

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- SJTU- International Copper Association- Hisense Kelon (Air Conditioner Company)
- 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 group will work in the coming period to develop a research project within the **ENERGIX program in the Norwegian Research Council** with a deadline in beginning of september 2014. The content will be clear in the period of the stay of Prof. Trygve M. Eikevik in July. It will also be checked if it is possible to apply for Chinese funding.



## Double Degree Master students

### SJTU students 2013

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

### SJTU students 2014

- JianRui Li
- Jinrui Zhang

### NTNU students 2013

- Hanne Thorshaug Andresen
- Jacob Mann

### NTNU students 2014

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

## 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 CO<sub>2</sub> as working fluid, Supervisor: Prof. Trygve M. Eikevik, Co-supervisor: Prof. Yong Li



# Summer School activities 2014/2015

- “*Heat Pumping Processes and Systems*”, July 2014  
Prof. Trygve M. Eikevik
- Energy in Buildings 2015 – Planning by the “Building” group

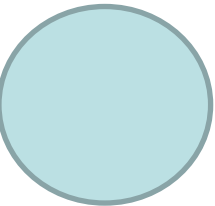


## 8. Calendar for 2<sup>nd</sup> part (autumn) of 2014 – Agreed dates for internet meetings

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- There will be a «Video» meeting in October



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# Thanks for your attention.



上海交通大学

Shanghai Jiao Tong University

Joint Research Centre  
In Sustainable Energy



**NTNU – Trondheim**  
Norwegian University of  
Science and Technology