# Heat pump/Air-Conditioner Performance Test Laboratory

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## Introduction

There are many types of heat pump/air-conditioning system used such as air-cooled split type, air-cooled compact, water-cooled chiller system. The performance of each system is much depended on its type and operation. The type of the system must be selected for specific design usage and operation. However, in many cases, the operation is far different from that of the design values. The performance, therefore, depended on each operation.

This experiment is to measure the performance of the special (non-industrial) configuration of air-conditioner, which comprised of water-cooled evaporator and air-cooled condenser. The system is assumed to work in air heating mode, so called heat pump (in this experiment), and water cooling mode, so called refrigerator or chiller (we are not doing). In normal practice only one function is desired. The coefficients of performance (COPs) are compared among actual operation and ideal operation by applying Carnot cycle.

# Objectives:

This experiment is helping students:

1. To learn the real components of a heat pump.
2. To learn the heat transfer mechanism which involves moist air and other fluids.
3. To determine the performance of heat pump/air-conditioning system for both heating and cooling modes.
4. To compare the actual coefficient of performance of the apparatus against that of Carnot and ideal cycles.
5. To examine the effects of water flow rate on COPs.

# Special topic

## Air velocity measurement by a pitot tube (brief version)

This experiment rig could be a heat pump or a refrigerator, depending on application. At the condenser, the heat is transferred to a moving air with a constant mass flow rate. The mass flow rate could be calculated by:

$$\dot{m} = \rho A \overline{U} \qquad kg/s$$

$\overline{U}$ is the average of all wind velocity values (U) across the air duct with cross sectional area of A (can be seen behind the rig), which could be simply calculated by:

$$\overline{U} = 0.96U \qquad m/s$$

$$U = 237.3\sqrt{\frac{H_{air}T_{DB,out}}{10 \times P_a}} \qquad m/s$$

Where:

$H_{air}$ = velocity head measured by the manometer, in $mmH_2O$,

$P_a$ is atmospheric pressure (Pascal) and $T_{DB,out}$ is dry-bulb temperature (°K) at the exit of the air duct.

# ME Experiment II 185 491

# Heat Pump Laboratory Description

WARNING:

Student who does not actively participate in his/her group will fail in the exam!

*เรียนจริง เจ็บจริง ตกจริง ในสลิง--- HEAT PUMP DANGEROUS!!!*

## Study Plan

Students will be given a pre-test (Cheat sheet) on the fundamentals of heat transfer, heat pump, air-conditioner and COP calculations. Therefore, it is compulsory that students go to e-learning and study all materials suggested.

Students will also be given a pre-test on the basic of thermocouple, flow rate conversion and electrical power calculation.

Suggested materials before pre-test:

Thermodynamics (an engineering approach)

Yunus A. Cengel & Michael A. Boles

6-4 Refrigerators and heat pump, p 293-296 (try all examples).

6-11 The Carnot refrigerator and heat pump, p 313-315 (try all examples).

11-1 Refrigerators and heat pump. p 624-630 (try all examples).

During the laboratory, students will be studying and setting up the following measuring equipment:

- Water flow meter
- Air flow measurement by pitot tube
- Thermocouple set up (rudimentary set up with voltmeter and thermocouple wire)

Students will be lectured on Carnot heat pump/refrigeration cycle, ideal heat pump/refrigeration cycle and real heat pump/refrigeration cycle.

Students will be lectured on psychrometrics.

Students will be instructed by a TA on the heat pump equipment: names, fluids and direction of flow.

# Tasks

Students participate in this lab must:

*In the first round*

1. Complete the pre-test.
2. Draw a detailed schematic diagram of the heat pump: equipment names, fluids, flow directions and heat transfer processes.
3. Draw diagrams of Carnot heat pump and real heat pump and identify $T_H$ and $T_L$.
4. Identify all thermocouple measuring points on the schematic diagram (students decide by themselves).
5. Design experiment procedure and data table and show calculation processes of
    - heat transfer calculation
    - $COP_{carnot}$ calculation
    - $COP_{max}$ calculation
    - $COP_{real}$ calculation
6. Explain what are $COP_{carnot}$, $COP_{max}$ and $COP_{real}$ calculation
7. Write a report and submit it in a *PDF file only* to akraphon@kku.ac.th.

*On the second round*

8. Perform the experiment.
9. Determine cooling water flow rate at the evaporator and moist air flow rate at the condenser.

10. Determine enthalpy change of moist air at the condenser by using psychrometrics chart/table.
11. Identify mode of heat transfer and calculate heat transfer at the condenser and evaporator.
12. Determine the $COP_{carnot}$, $COP_{ideal}$ and $COP_{max}$ of the heat pump.
13. Write a report and submit it in a ***PDF file only*** to akraphon@kku.ac.th.

## Skills Acquirable From This Laboratory

Students will gain invaluable skills in the following topics:

- Rudimentary set up and calculation of thermocouple
- Basic air flow measurement by pitot tube
- Basic fluid mass flow measurement
- Dry air/moist air enthalpy determination
- Basic principles of heat pump/refrigerator
- Applied principle of heat pump/refrigerator
- Applied principle of COP and energy conversion

# Core Understanding and Discussion Topics

Student should be able to understand and discuss to further his/her knowledge in the following topics:

- Heat pump A has 5-stars energy label and heat pump B has 3 stars energy label. If they are used to keep a house at 20 ºC, while the outside temperature is 0 ºC, what is the difference between the heat pump A's $COP_{carnot}$ and heat pump A's $COP_{carnot}$? and why?
- From heat pump experiment, where water flow rate passing through the evaporator can be adjusted, it was found that the Coefficient of Performance ($COP_{refrigeration}$) rose when the water flow rate was increased. Student must give the explanation to why the system performance increased.
- Student must explain what would happen to the Coefficient of Performance ($COP_{heatpump}$) if air flow through the condenser is increased by larger electric fan and what will be the disadvantage in this case.
- To increase $COP_{heatpump}$ and $COP_{refrigeration}$ in the experiment, what should be done to the condenser and evaporator if flow rates cannot be increased? (10%)
- Why heating using a heat pump save more energy than heating using electric heater or gas heater?