CEEE CENTER *for* ENVIRONMENTAL ENERGY ENGINEERING

Experimental Investigation of Multi-Functional Variable Refrigerant Flow System

#2375

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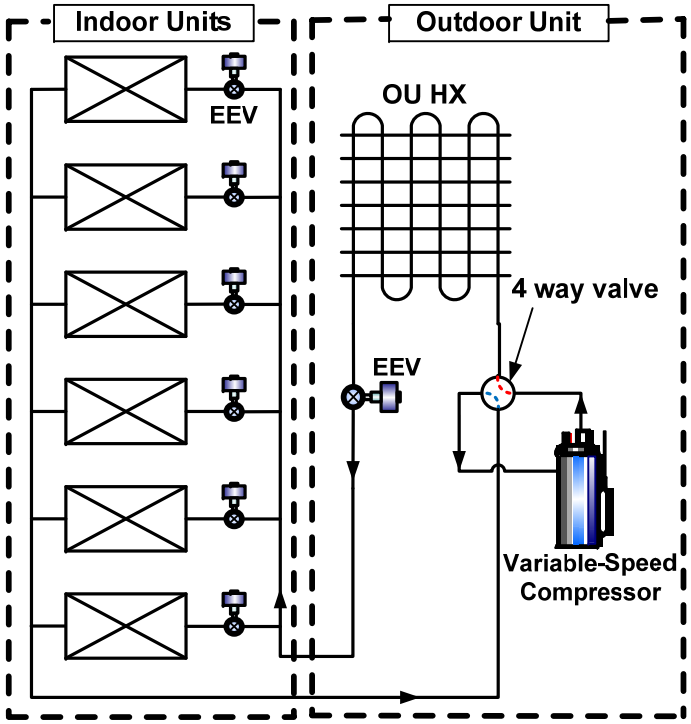
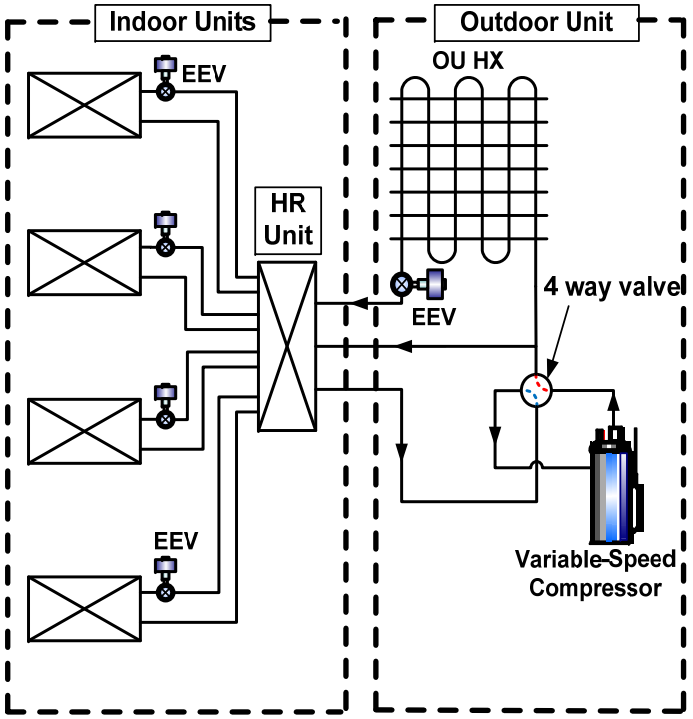
CEEE

Background

- Heat Pump VRF (HP-VRF)



- Heat Recovery VRF (HR-VRF)



- VRF systems has a better installation flexibility compared to VAV
- Variable refrigerant flow (VRF) system provides precise control of the indoor units
- HP-VRF provides either cooling or heating
- HR-VRF provides simultaneous cooling and heating

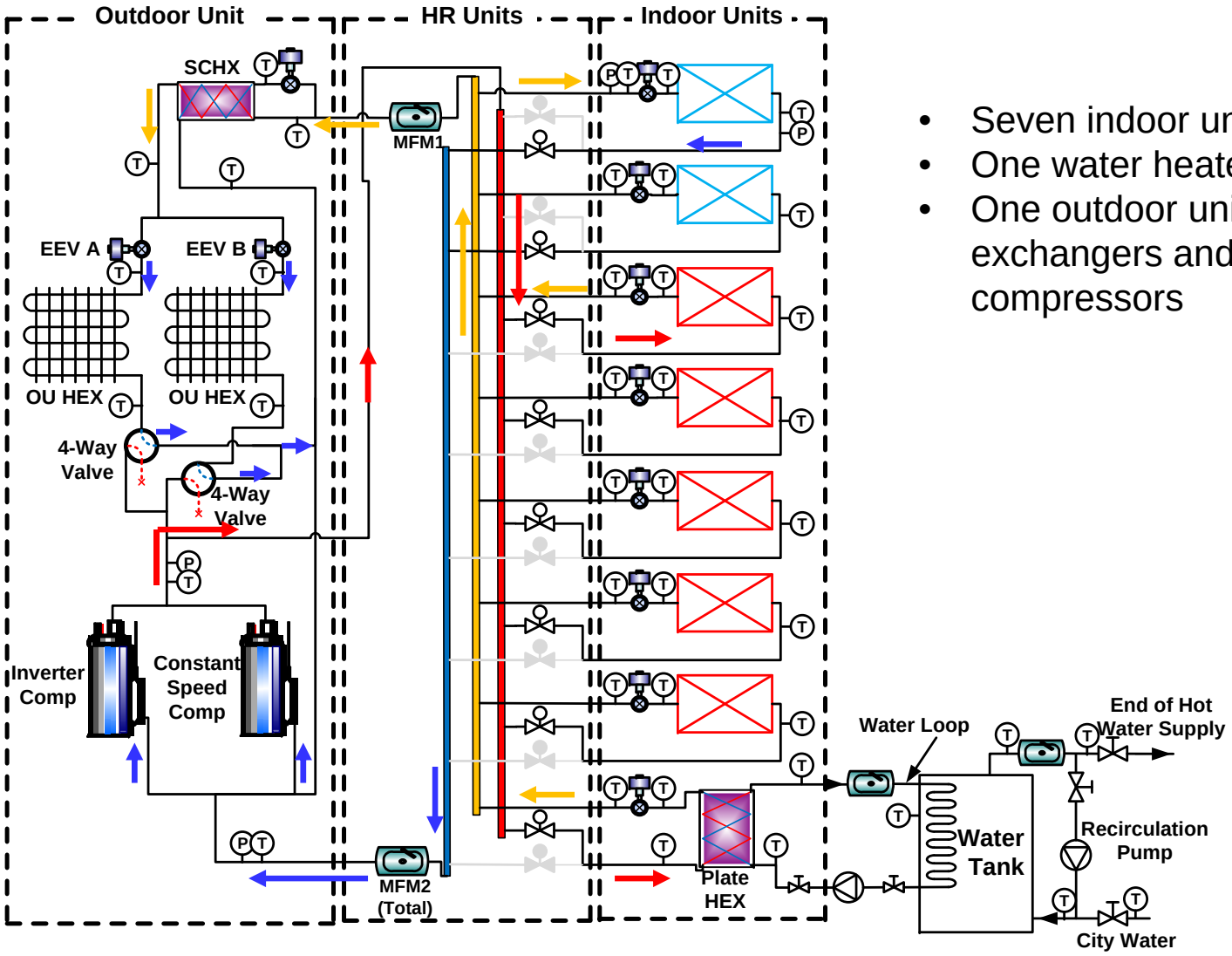
Motivation

- Compared with HP-VRF, the part load performance of the HR-VRF system, is rarely discussed.
- The possibility and potential of providing residential hot water to the building with VRF system is rarely considered.
- The heat recovery operation of the HR-VRF system under actual ambient condition needs more investigation.

Objective

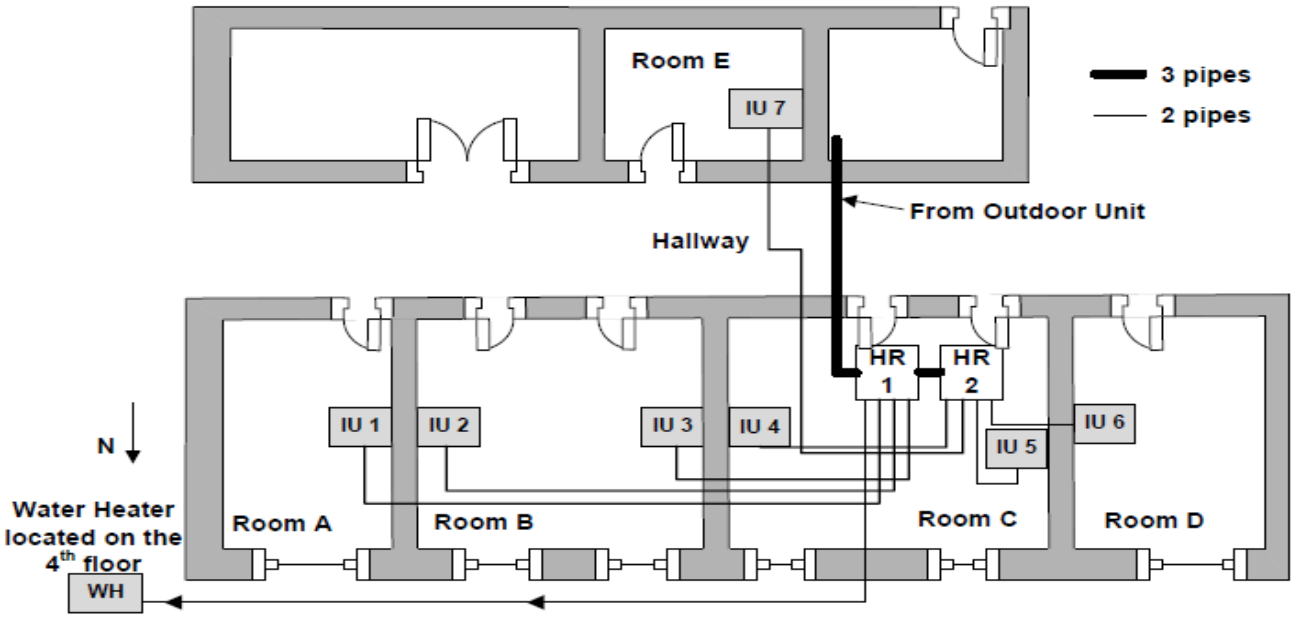
- Investigate the field performance of the a multi-functional variable refrigerant flow (MF-VRF) system with water heating capability
- Investigate the effect of water heating component upon the MF-VRF system
- Investigate the effect of heat recovery operation of the MF-VRF system

Schematic of Refrigerant System



- Seven indoor units
- One water heater
- One outdoor unit with two heat exchangers and two compressors

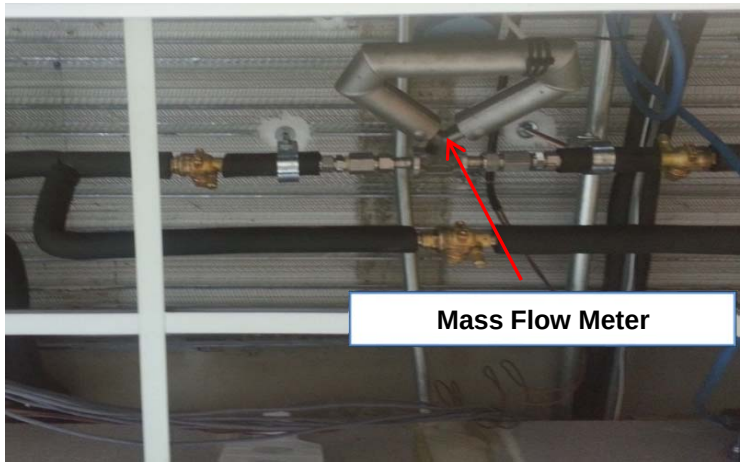
Building Layout



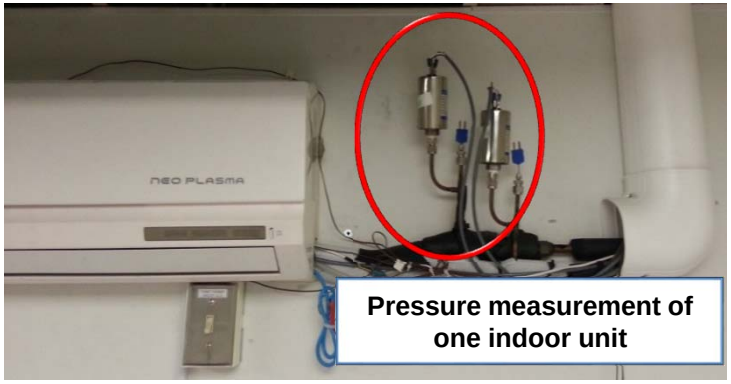
Layout of the Education Building

		Outdoor Unit	**Hydro Kit**	**Indoor Unit #1,#6,#7**	**Indoor Unit #2,#3**	**Indoor Unit #4,#5**
Capacity	Cooling (kW)	35.2	14.1	5.6	3.6	2.2
	Heating (kW)	39.6	15.9	6.3	4.0	2.5
Refrigerant		R410A				

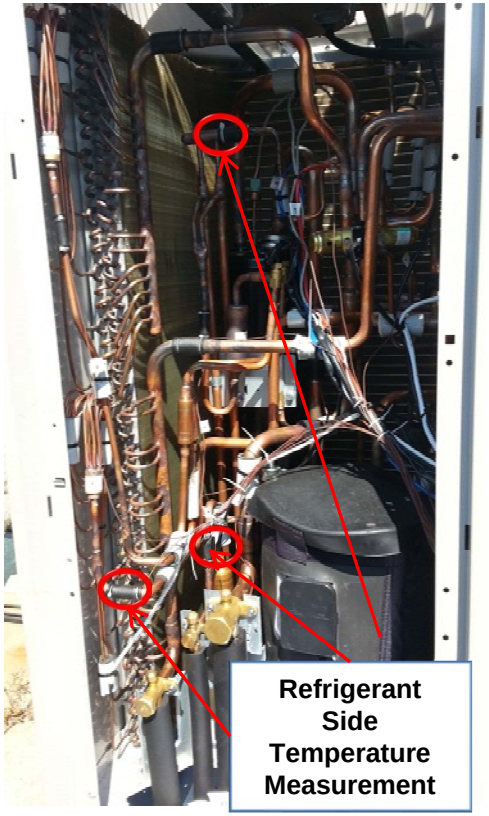
Instrumentation



- Refrigerant side mass flow rate



- Refrigerant side pressure



- Refrigerant side temperature

Data Reduction

- **The refrigerant mass flow rate of each indoor unit**

1st $\dot{R}_i = C_d A\sqrt{2\Delta P\rho}$ (EEV correlation)

2nd $\dot{m}_i = \frac{R_i}{\sum_{i=1}^{n} R_i} m_{total}$ (Corrected mass flow rate)

- **Part load ratio (PLR)**

$$PLR = \frac{\dot{Q}_{heating,total} + \dot{Q}_{cooling,total} + \dot{Q}_{waterheater}}{\dot{Q}_{heating,rated}}$$

- **Hourly performance factor (HPF)**

$$HPF = \frac{\sum \dot{Q}_{heating,total} + \sum \dot{Q}_{cooling,total} + \dot{Q}_{waterheater}}{\sum (P_{OU} + P_{IU} + P_{pump})}$$

- **Daily performance factor (DPF)**

$$DPF = \frac{\sum \dot{Q}_{heating,total} t + \sum \dot{Q}_{cooling,total} t + \dot{Q}_{waterheater} t}{\sum (P_{OU} + P_{IU} + P_{pump}) t}$$

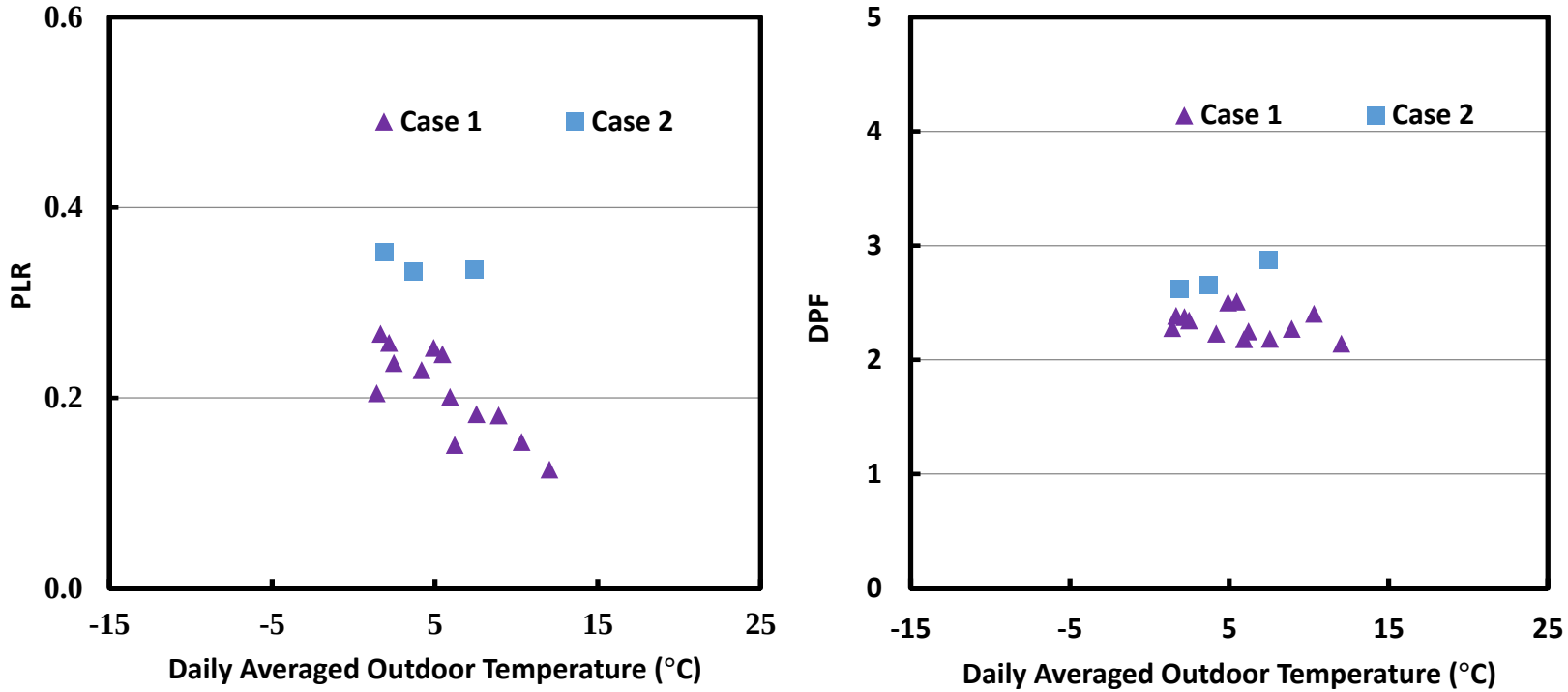
Test Conditions

- **Operating Conditions**
  - The set point of hot water tank was 50°C
  - The set point of the cooling indoor units was 27°C and the set point of heating units was 20°C.
  - The location of building: College Park, Maryland, USA
  - The testing period: Dec/2013 – March/2014
- **Test Matrix**

Test mode	Cooling Units	Heating Units	Daily Hot Water Consumption (liters/day)	Ratio of Nominal Cooling Capacity to Nominal Heating Capacity
Case 1	IU #7	IU #1 #2 #3 #4 #5 #6	0	0.09
Case 2	IU #7	IU #1 #2 #3 #4 #5 #6	738	0.05
Case 3	IU #4 #5	IU#1 #2 #3 #4 #5 #6 #7	0	0
Case 4	None	IU #2 #3 #6 #7	0	0

Test Results

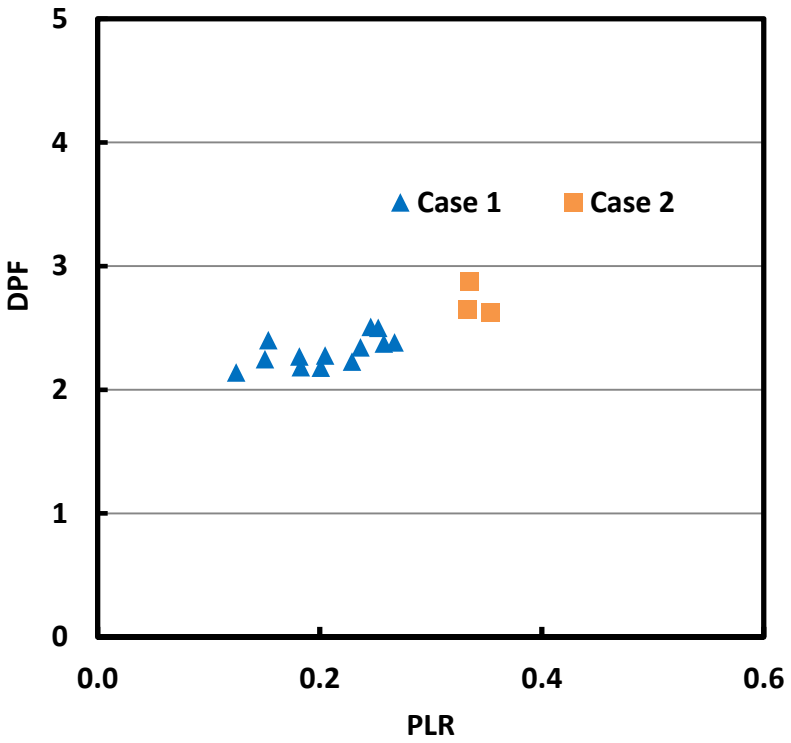
- **Effect of hot water operation**

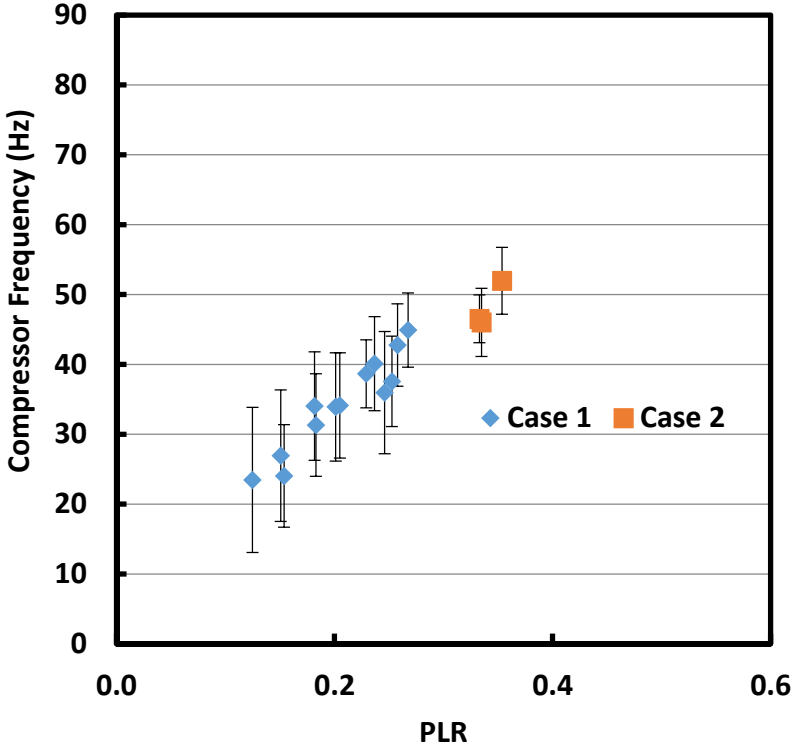


- When ambient temperature is 5°C, part load ratio of the system increases by 65%, with a value of 0.34 when the hot water operation is on.
- The daily performance of the system is improve,accordingly.

Test Results

- **Effect of hot water operation**

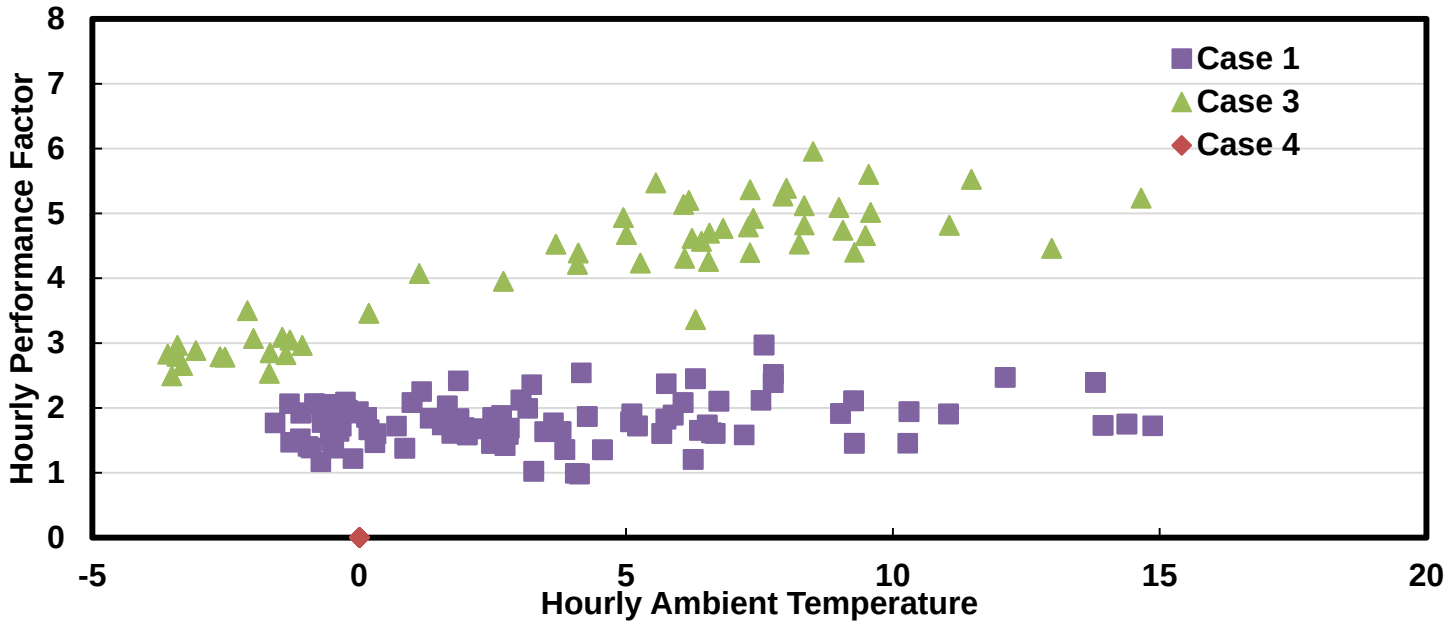




- The compressor cycling loss is reduced with a higher PLR.
- When the ambient temperature is around 5°C, the daily performance factor is increased by 17%, with a value of 2.7.

Test Results

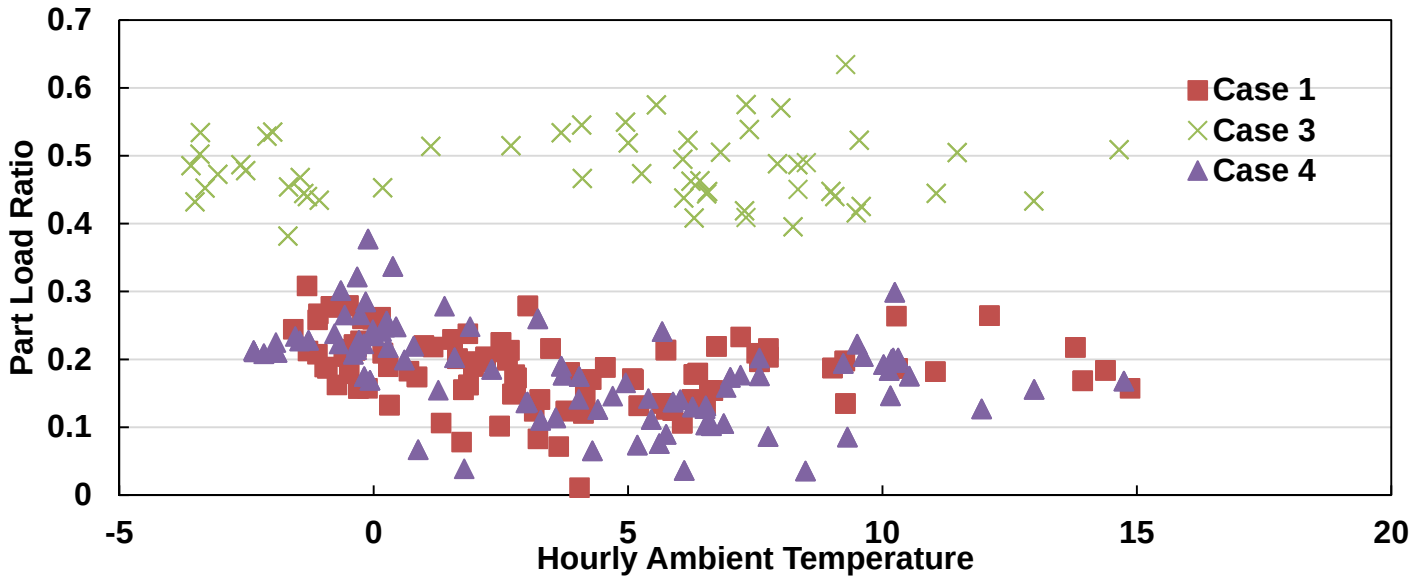
- **Effect of heat recovery operation**



- With only unit (IU #7) in cooling mode, the effect of heat recovery operation is not obvious. This is due to the fact that Room E has a high internal load and the cooling load in winter is rather small.
- With two units in cooling, the hourly performance factor is increased.
- The HPF with heat recovery operation reached 3.5 when the ambient temperature is near 0°C

Test Results

- **Effect of heat recovery operation**



- With only unit (IU #7) in cooling mode, the part load ratio of the system is no increased.
- With two units in cooling, the part load ratio of the system is increased by 0.2 when the ambient temperature is around 0°C

Conclusions

- The field performance testing of a multi-functional variable refrigerant flow (MF-VRF) system with water heating capability was conducted
- With water heater in operation, the part load performance of the system is improved. The daily performance factor was increased by 17%
- With the heat recovery operation, the hourly performance factor of the system is improved from 2.6 to 3.4 due to the decreased pressure ratio

Future Work

- Investigate the effect of heat recovery operation under a wider temperature range
- Investigate the effect of hot water consumption profile
- Investigate the effect of hot water tank set point
- Investigate the effect of heat recovery operation under a wider cooling energy ratio

Acknowledgement

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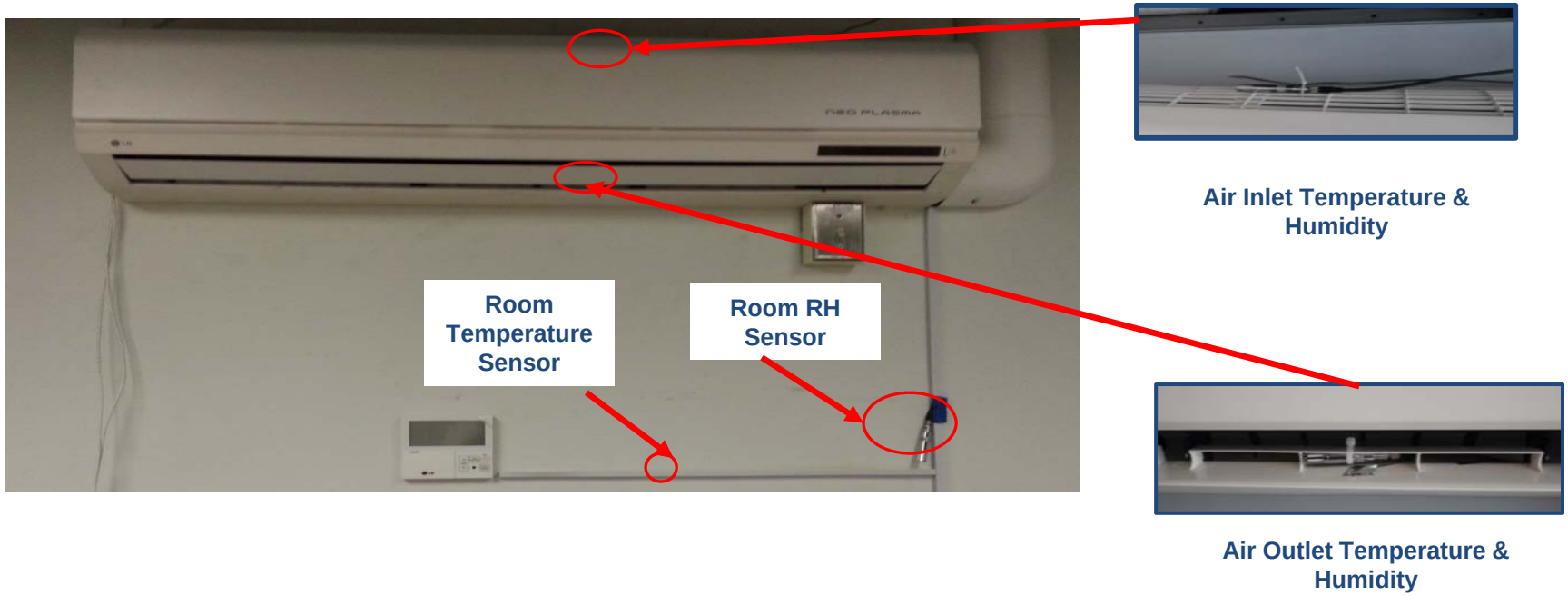
Thank You

Backup

Instrumentation



- Air side measurement including the temperature and humidity.
- The air side instrumentation includes T-type thermocouples and RH sensors