Seminar 53 – HVACR Novel Measurement Techniques: The Next Generation

2018 ASHRAE ANNUAL CONFERENCE
Houston, TX | June 23-27, 2018

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A Novel Measurement Technique for Refrigerant and Oil Charge Measurements in Heat Exchanger Coils (ASHRAE RP-1785)

Learning Objectives

- Explain high level operating principles of fiber optic temperature measurement techniques
- Understand currently used and new techniques to determine average and local air-side heat transfer coefficients
- **Understand of the different measurement methods that can be used for refrigerant and oil charge measurements**
  - ✓ **In-depth understanding of the charge measurement method used in ASHRAE RP-1785**
  - ✓ **Comparison of existing charge measurement methods**
- Explain the relationship between the measured capacity and the void fraction

Acknowledgements

I would like to thank:

- Dr. Bach and Dr. Bradshaw - advisors
- Project management subcommittee (PMS)
- Sponsoring and co-sponsoring committees
  - TC 8.11, TC 8.4, and TC 6.3
- JCI, especially Dr. Kishan Padakannaya
- Harrison-Orr, especially Damon D. McClure

Outline

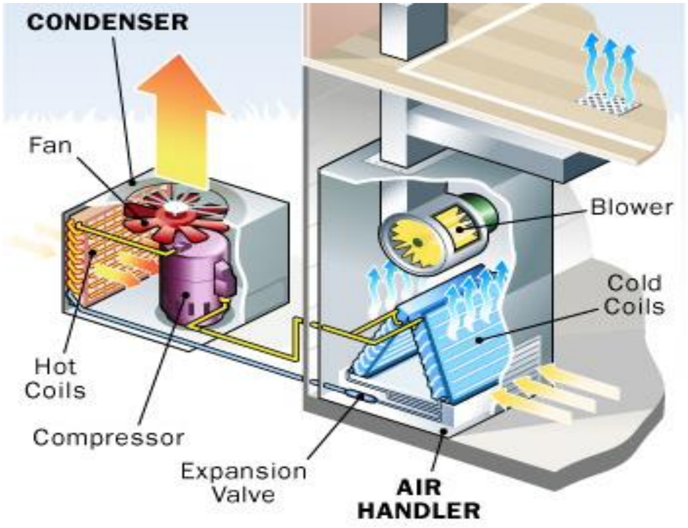
1. Objectives / Motivations
2. Charge measurement methods
3. Setup components
4. Test matrix
5. Current status
6. Conclusions / Future work

Objectives

- **Goal**
  : Provide accurate data for oil retention and refrigerant charge for 3-ton coils

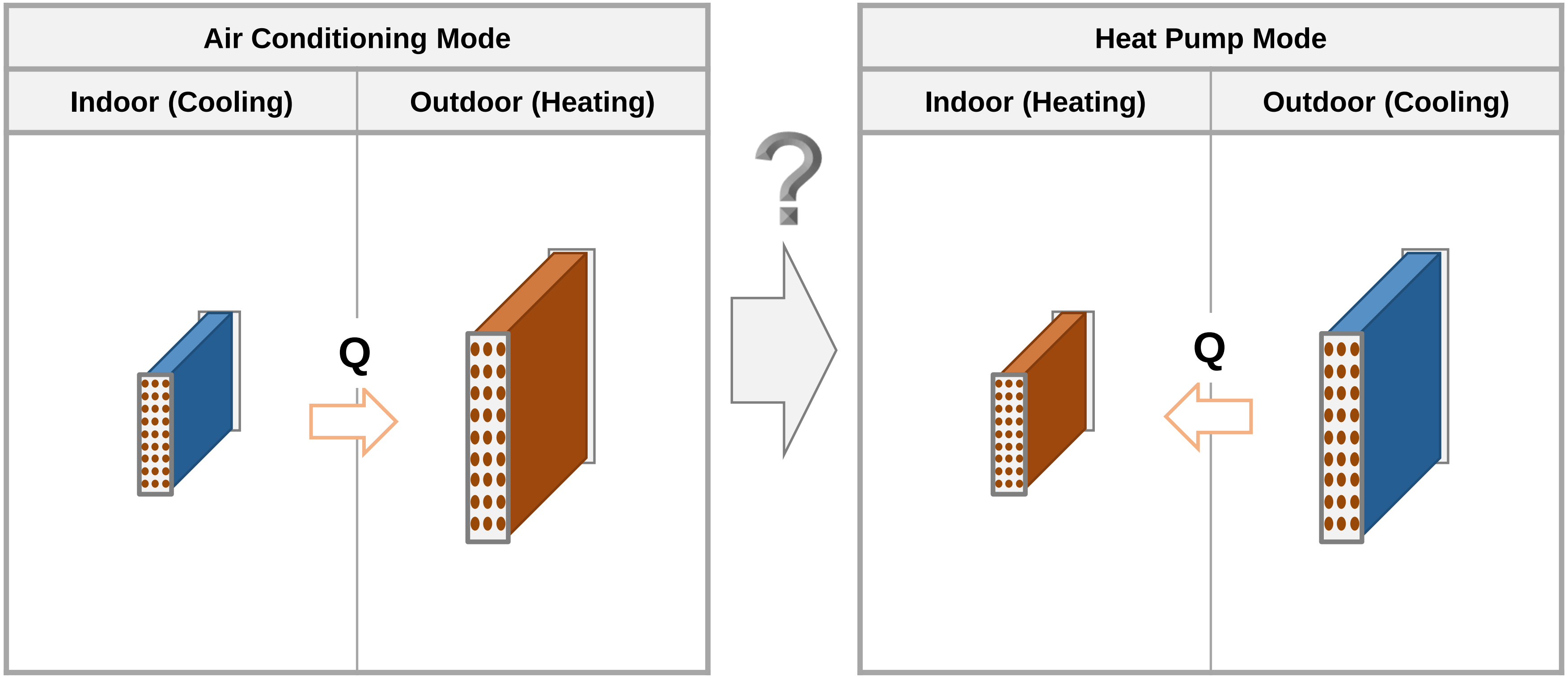
- **Round Tube Plate Fin Heat Exchangers**

- **Residential Split Systems**



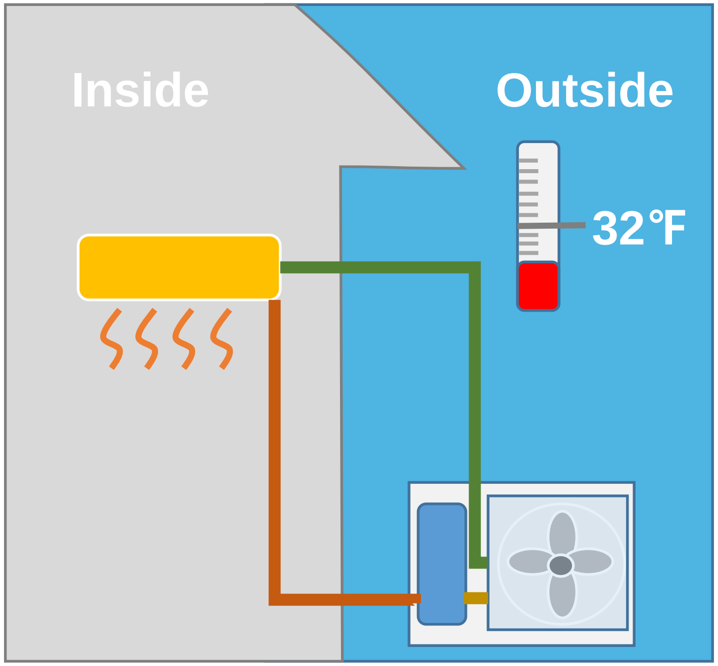
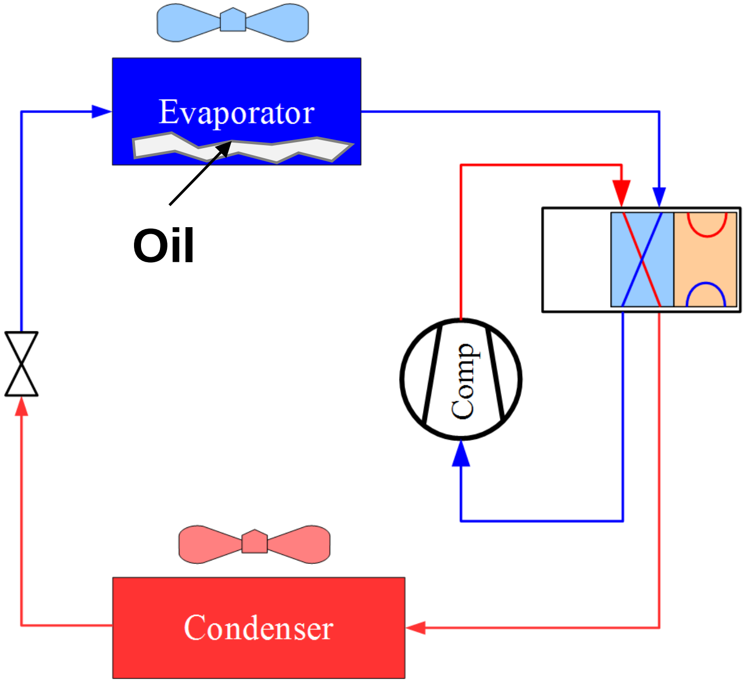
Refrigerant Charge Data Needed

- **Charge balance for switching AC & HP mode - maintain optimal performance?**



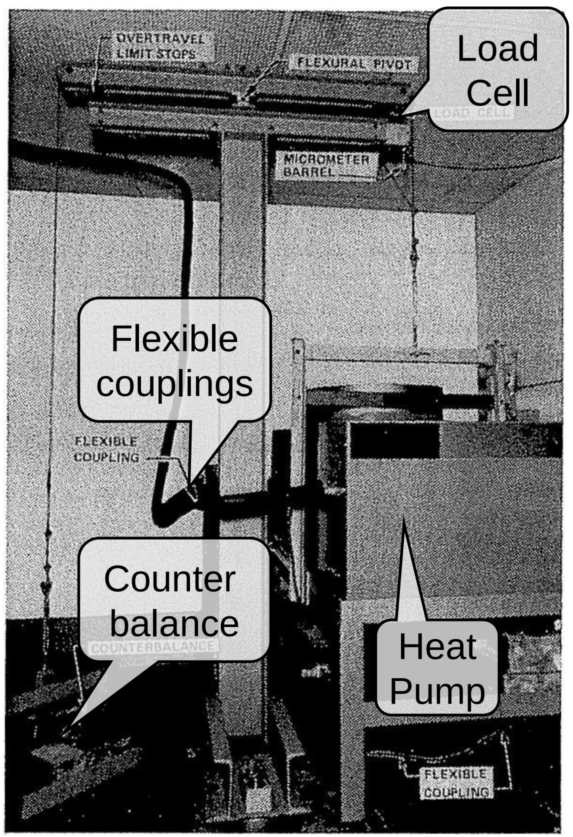
Oil Retention Data Needed

- **How much oil needs to be pre-charged to ensure reliable operation?**

Oil Migration in Heat Pump	Oil Accumulation at Low Ref. Flowrates
	

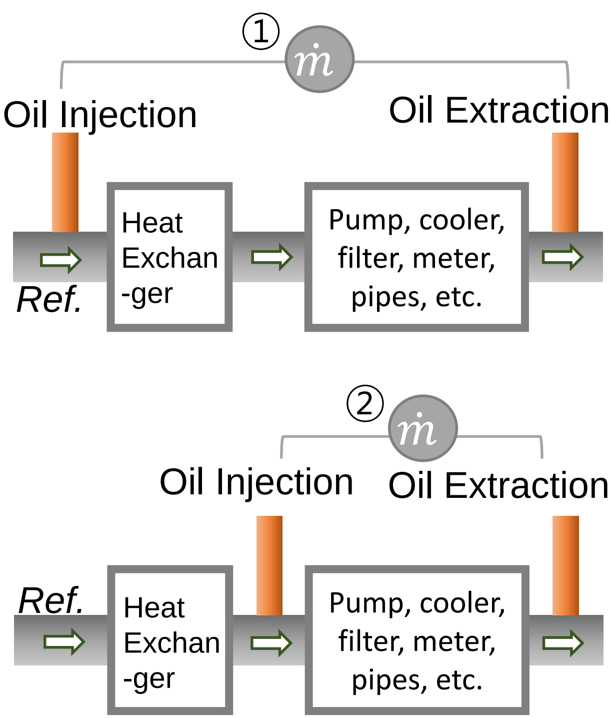
Some Examples of Charge Measurement Methods

Online Weighting Technique



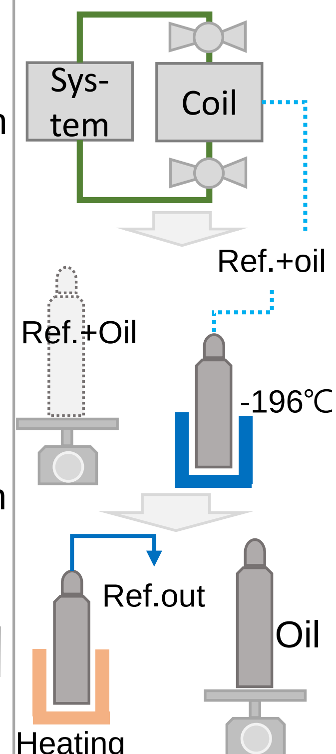
Online Transient Technique

Oil retention in Coil = ① — ②

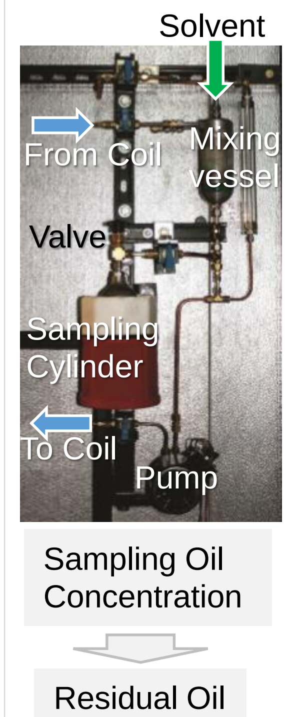


Sampling Measurement Technique (Mix and Sample)

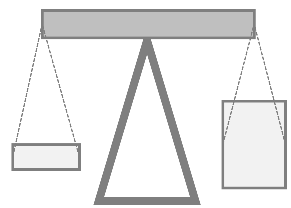
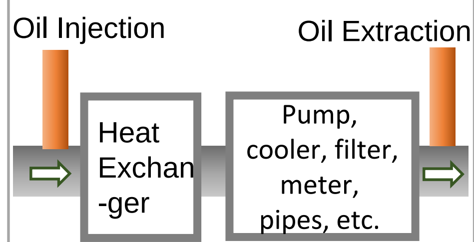
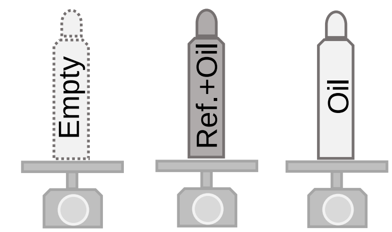
(Ref.+oil in Coil)



(Residual oil in Coil)



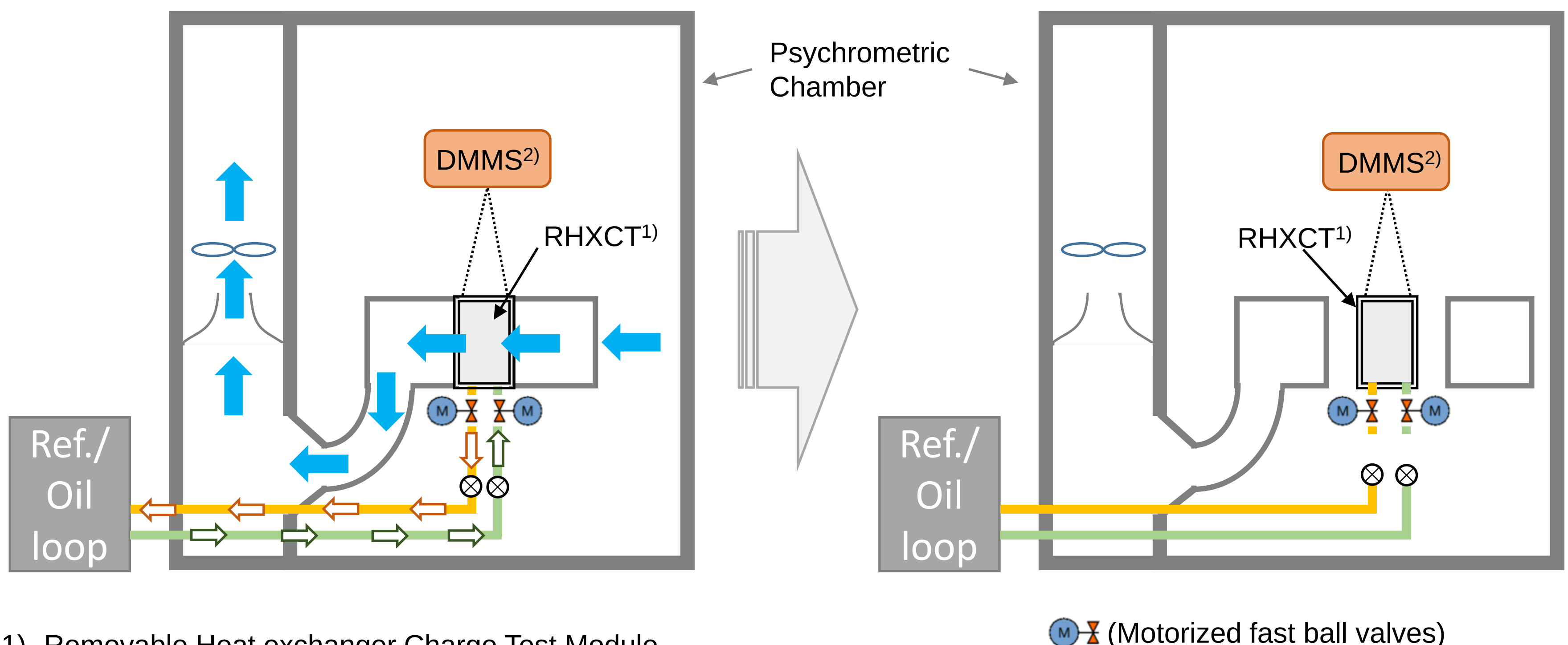
Comparison of The methods

	Online Weighting Technique	Online Transient Technique	Sampling Measurement Technique
Schematic			
+	✓ **FAST** • No sampling process	✓ **FAST** • No disassembling the test section • No recovering of the refrigerant after each test	✓ **MORE ACCURATE** • Using isolated sample
−	✓ **NO SEPARATION** • Between oil and refrigerant ✓ **LIMITED ACCURACY** • Fan thrust, connection lines	✓ **LIMITED ACCURACY** • Injection and extraction induce transient behavior of the system • Extraction efficiency varies with operating conditions	✓ **SLOW** • Multi Sampling process is needed

RP1785 Method

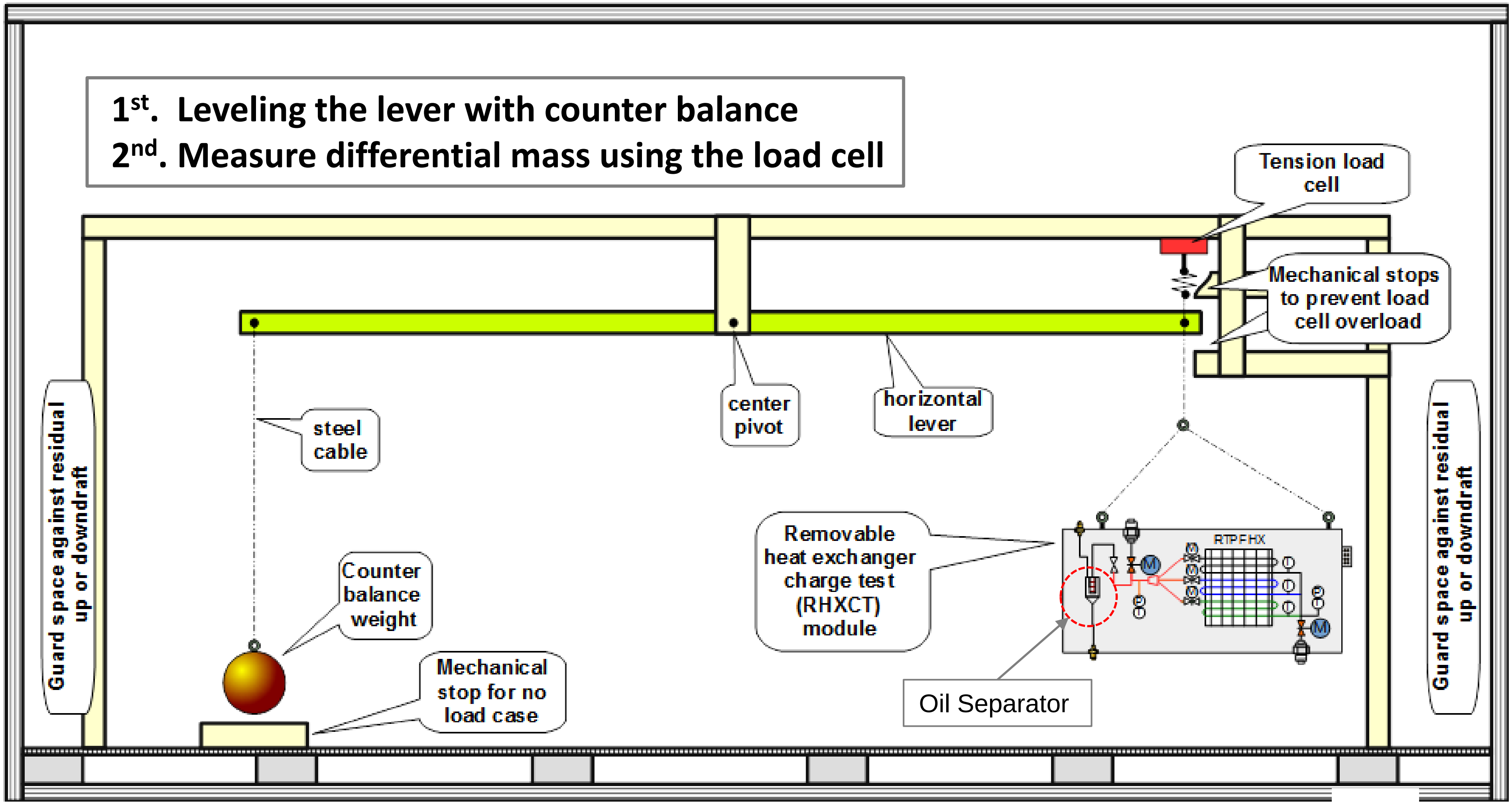
- REMOVE 'N WEIGH technique
- Quickly close inlet and exit shut-off ("sampling")

- **Operating Mode (steady-state)**
- **Charge Sampling Mode**



1) Removable Heat exchanger Charge Test Module
2) Differential Mass Measurement Scale

Differential Mass Measurement Scale (DMMS)



Measurement Steps

Steps	1st	2nd	3rd
RHXCT Contents	DMMS2) — DRY RHXCT	DMMS2) — DRY RHXCT + Oil + Refrigerant +	DMMS2) — DRY RHXCT + Oil1)
Execution	▪ Before Operation	▪ After Operation	▪ After Refrigerant Evacuation
Measurement Methods	▪ Weigh the evacuated RHXCT	▪ Quickly close inlet and exit	▪ Evacuate refrigerant only (with oil separator)

1) Refrigerant dissolved in the oil is negligible if evacuated to 10,000 microns or less
2) Differential Mass Measurement Scale

Charge Calculation

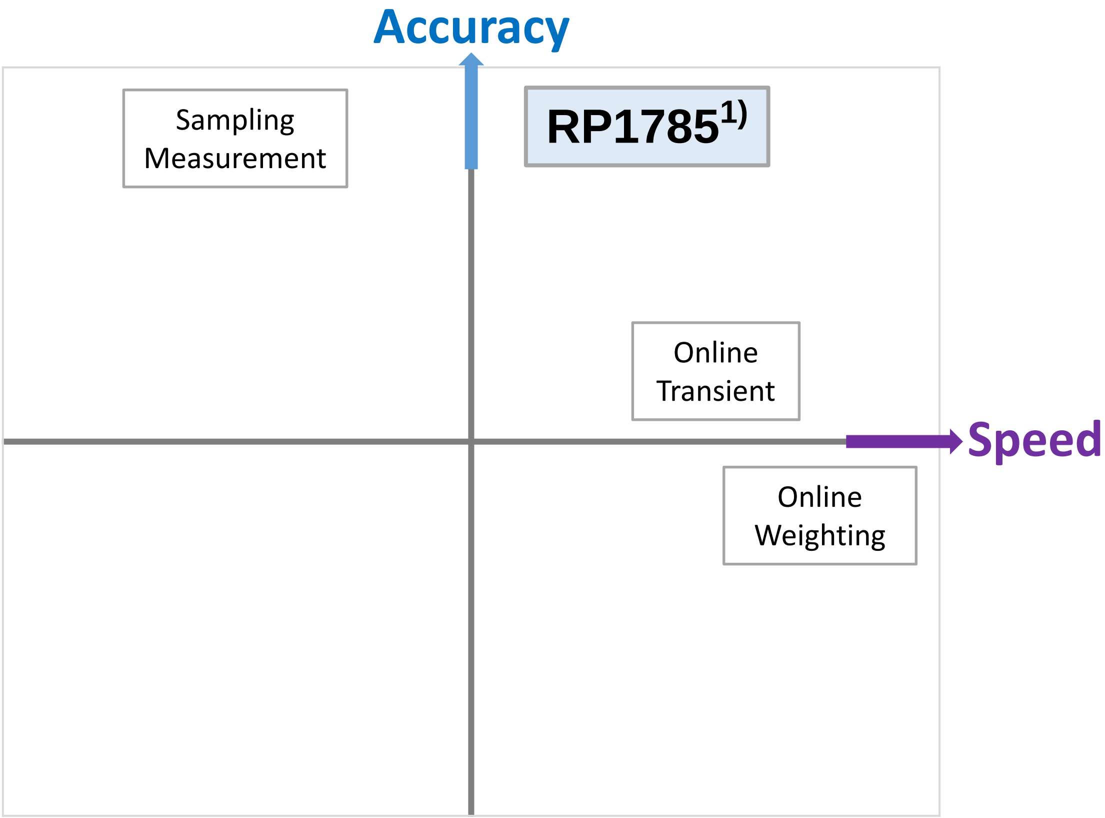
Refrigerant Mass = [DMMS: DRY RHXCT[2] + Oil + Refrigerant] — [DMMS: DRY RHXCT[2]] — [DMMS: DRY RHXCT[2] + Oil[1]]

Oil Mass = [DMMS: DRY RHXCT[2] + Oil[1]] — [DMMS: DRY RHXCT[2]]

1) Refrigerant dissolved in the oil negligible if evacuated to 10,000 microns or less
2) Removable Heat exchanger Charge Test Module

RP 1785 Charge Measurement Method Benefits

- **Comparison**



- **Benefits**

✔ **SIMPLE** - No complicated mixing step needed

✔ **HIGH ACCURACY** - Sampling method

✔ Oil and refrigerant **DETERMINED SEPARATELY**

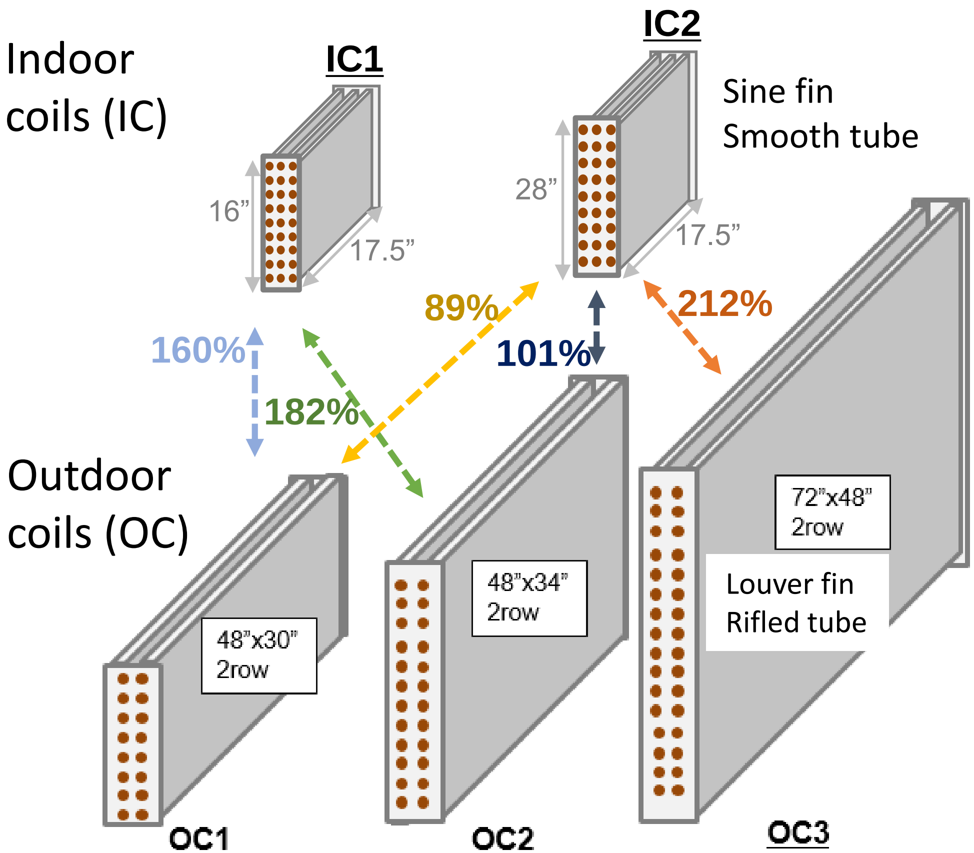
✔ **FASTER** than sampling technique- Refrigerant setup in standby mode

1) Differential mass evacuation sampling technique

Test Matrix

- Providing different Outdoor coil/Indoor coil volume ratios

- **Coil information**



- **5 different indoor/outdoor coil combination**

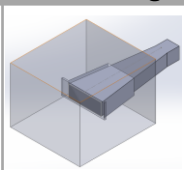
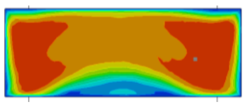
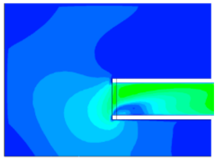
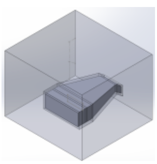
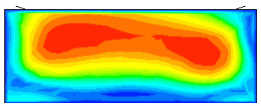
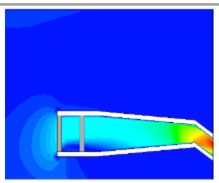
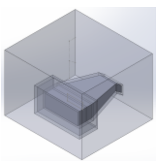
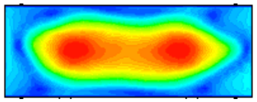
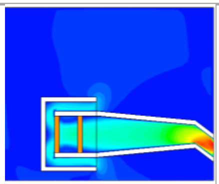
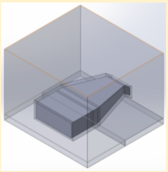
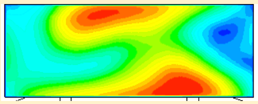
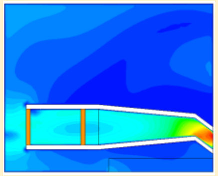
Outdoor coil/Indoor coil ratio[1)]		Indoor coil	
		IC1[2)]	IC2[2)]
Outdoor coil	OC1	160%	89%
	OC2	182%	101%
	OC3	N.A	212%

1) The internal volume of outdoor coil / the internal volume of indoor coil
2) Two slabs used in the calculation, to reflect actual product applications (*e.g.* A-coils)

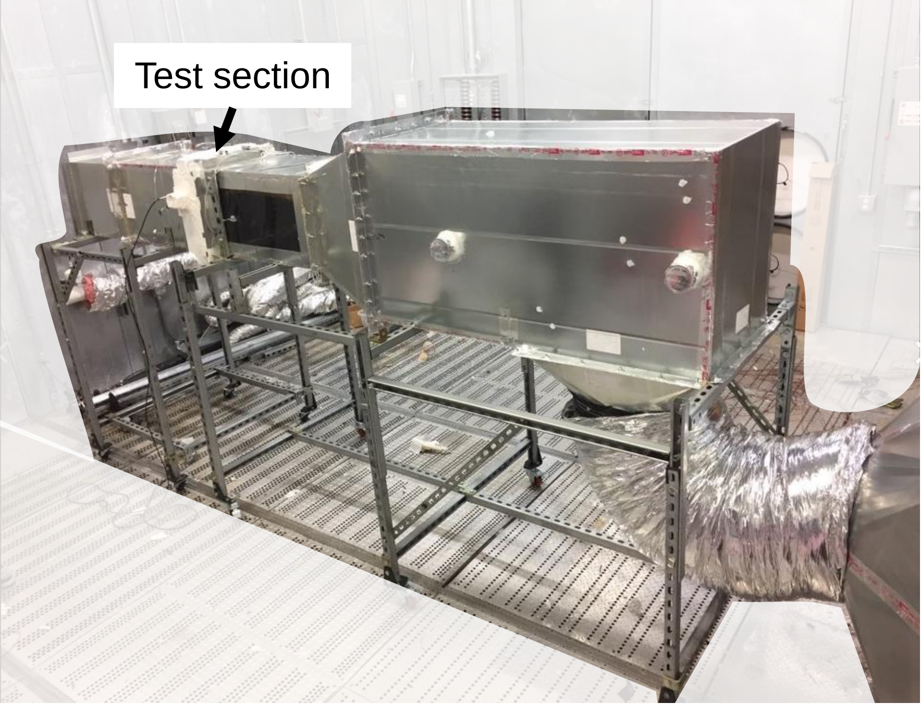
Current Status

- **A duct for IC1 is completed**
- **CFD results informed the design of the duct**

- **CFD results**[1)]

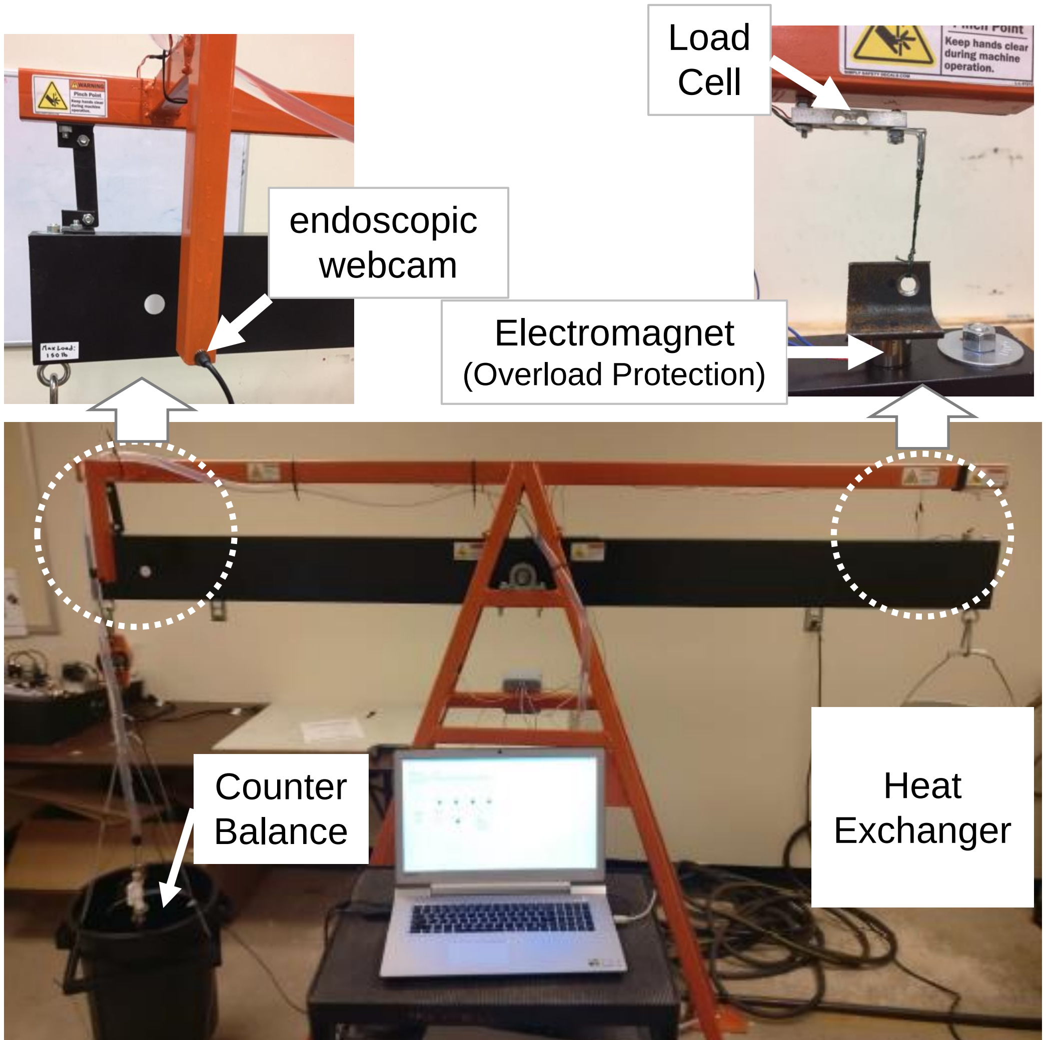
Airflow Uniformity[2)]	CFD Modeling	Velocity contour on the coil	Velocity contour at the side view
0.22 (100%) Baseline			
0.36 (164%)			
0.53 (241%)			
0.31 (141%)			

- **IC1 Duct**



1) See Lee(2018) for details: OC3 is employed in CFD
2) Standard deviation of velocity on the coil [m/s]

Prototype of Differential Mass Measurement Scale (DMMS)

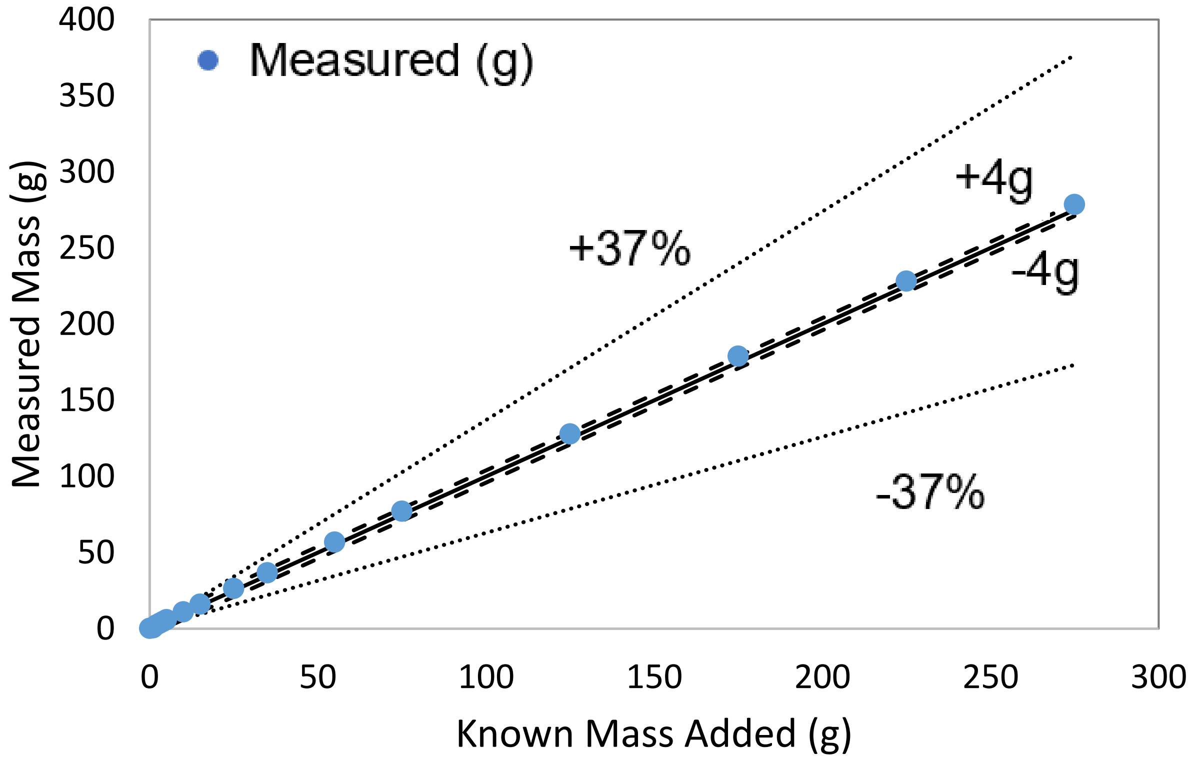


- **Specifications**

	Value	Note
Heat exchanger Total mass range	5~40kg	-
Expected charge load	1~275g	-
Load cell limit	500g	-
Load cell accuracy	0.1g	0.02% for 500g

Differential Mass Measurement Scale (DMMS) Accuracy

- Accuracy: 4g or 37% whichever is lower



Measured for 5.2kg “RHXCT” weight

Conclusion

- **RP1785 is the differential mass evacuation sampling method that take advantages of two existing charge measurement methods**
- **Since sampling measurement technique is employed in RP1785, it is reliable and accurate.**
- **RP1785 method is relatively fast and simple because there is no complicated sample measurement procedure**

Future Works

- **Complete Oil and Refrigerant setups**
- **Calibrate instrumentation**
- **Tests to confirm repeatability and accuracy of differential mass measurement scale (DMMS)**

Bibliography

- Jin, S. (2012). *Distribution of refrigerant and lubricant in automotive air conditioning systems*. Thesis, University of Illinois at Urbana-Champaign.
- Miller, W. (1985). *The Laboratory Evaluation of the Heating Mode Part-Load Operation of an Air-to-Air Heat Pump*. ASHRAE Transactions. Vol, 91. Part 2B. HI-85-10 No. 2.
- Juseok(Abraham) Lee, Christian K. Bach, Craig R. Bradshaw (2018). *CFD Case Study: Heat Exchanger Inlet Air Velocity Distribution for Ducted Tests in a Psychrometric Chamber (ASHRAE RP-1785).* International Refrigeration and Air Conditioning Conference at Purdue
- Cremaschi; L., Fisher, D. E., Yatim, A., Deokar, P., Bigi, A. M., Mulugurthi, S., Dell'Orto S. (2015). *RP-1564 -- Measurements of Oil Retention in Microchannel Heat Exchangers.* ASHRAE Research Report.
- Bach, C.K., Bradshaw, C.R. (2017). *Experimental Validation of Refrigerant Charge Models in Coils for Residential Split Systems.* Proposal for Research on ASHRAE Project 1785-TRP.

Credits

- RP 1785 PMS members
- RP 1785 Oklahoma State University team members:
  Christian Bach(PI), Craig Bradshaw (Co-PI), & others
- Oklahoma State University, MAE 4344 Senior Design DMMS2 Team
- HowStuffWorks2009

Thank you for your attention!

Questions?

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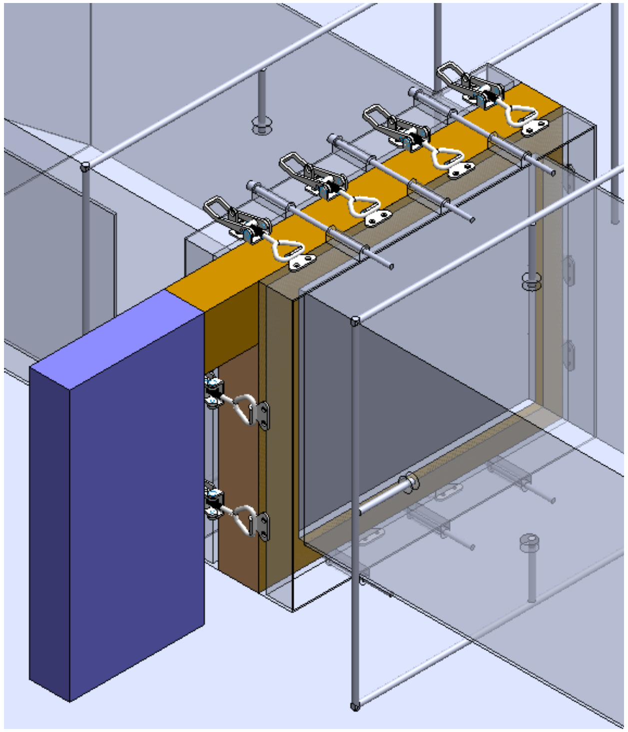
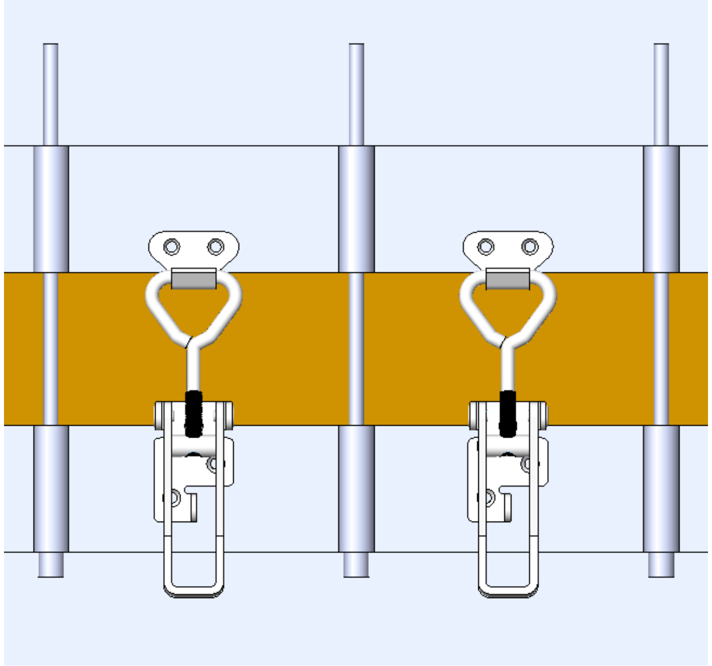
Appendix

RHXCT[1)] (Connected)

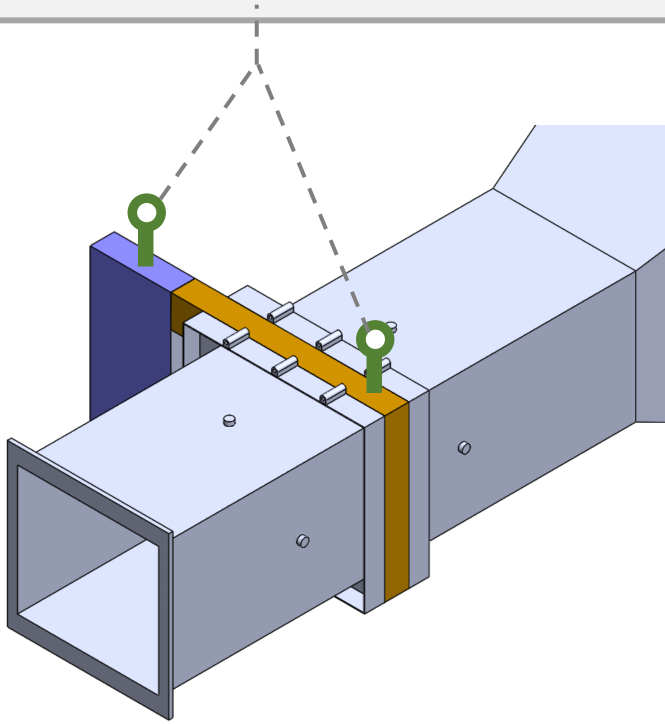
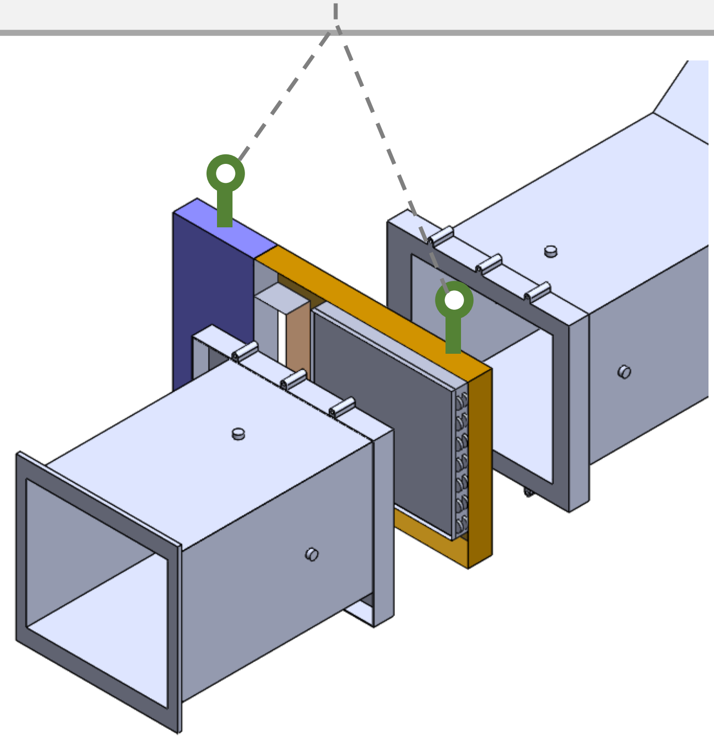
- **Quick disconnect available**

Isometric view	Latch Clamps & Align pins
	

1) Removable Heat exchanger Charge Test Module

RHXCT[1)] (Disconnected)

- **The differential mass obtained by removing RHXCT**

Connected	Disconnected
	

1) Removable Heat exchanger Charge Test Module

Online Transient Method

- The injection and extraction flow rates becomes steady approximately at time t2
- From time t2 to time t3, the average difference between the oil mas injected and the oil mass extracted from the refrigerant loop resulted in the **oil mass that was held up in the microchannel condenser plus all connecting pipelines between the condenser and the oil separators.** This mass is referred to as Ma in Figure 1(a).

$$M_{oil,retention} = M_a - M_b$$

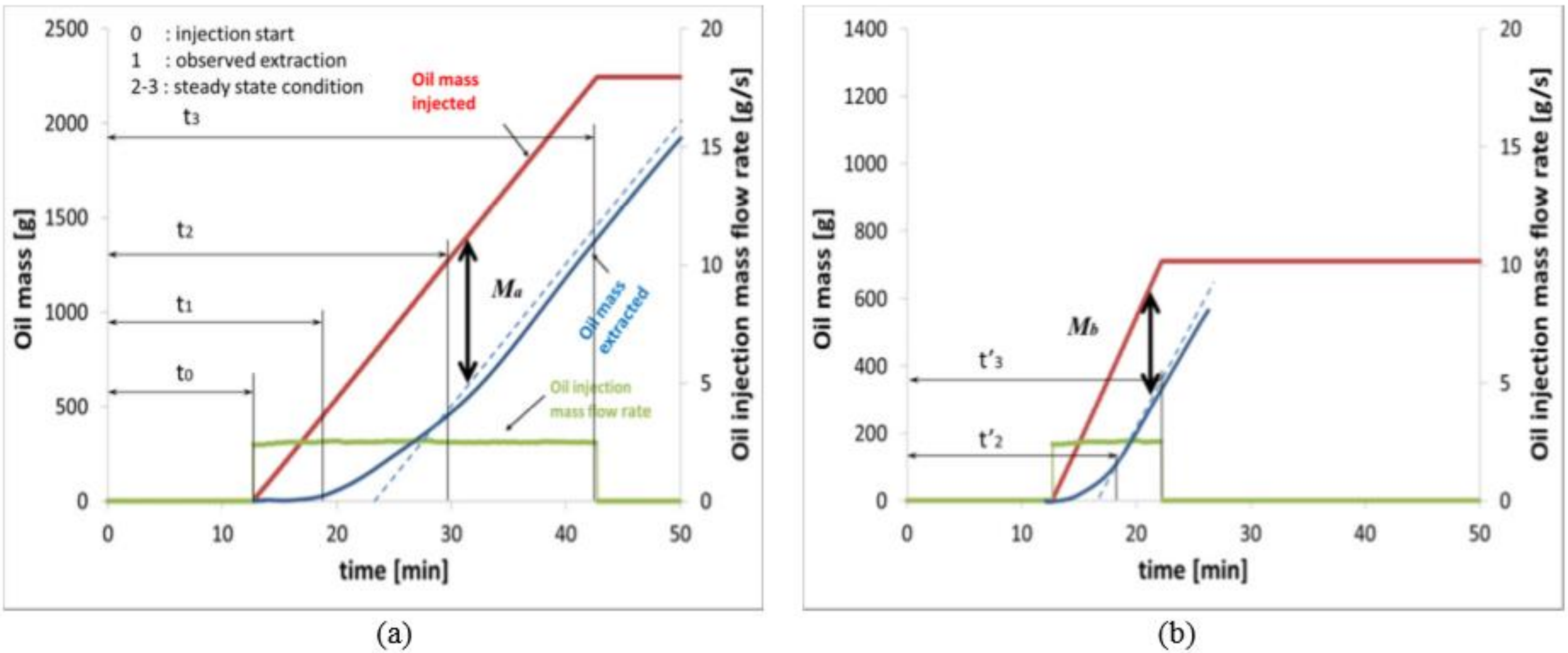


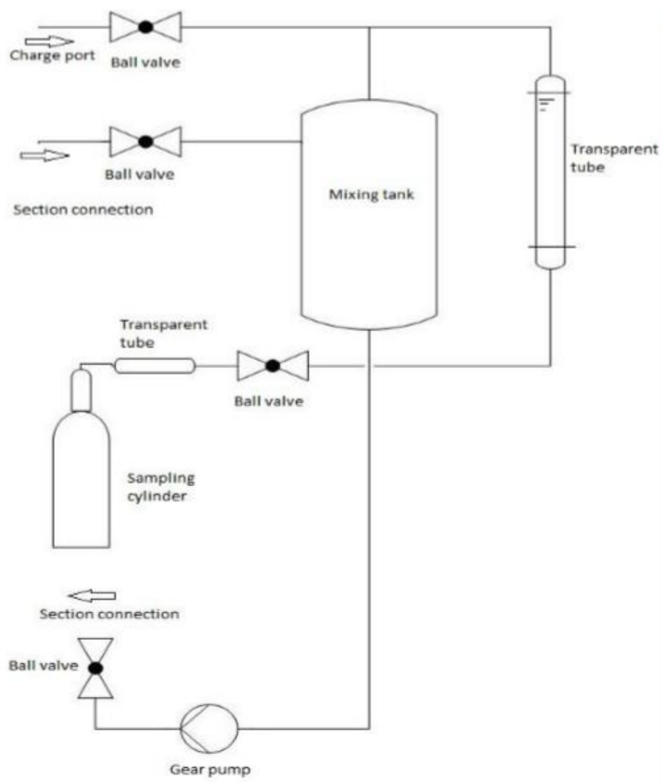
Figure 1: *Oil retention measurement at inlet (a) and at outlet (b) of the test section*

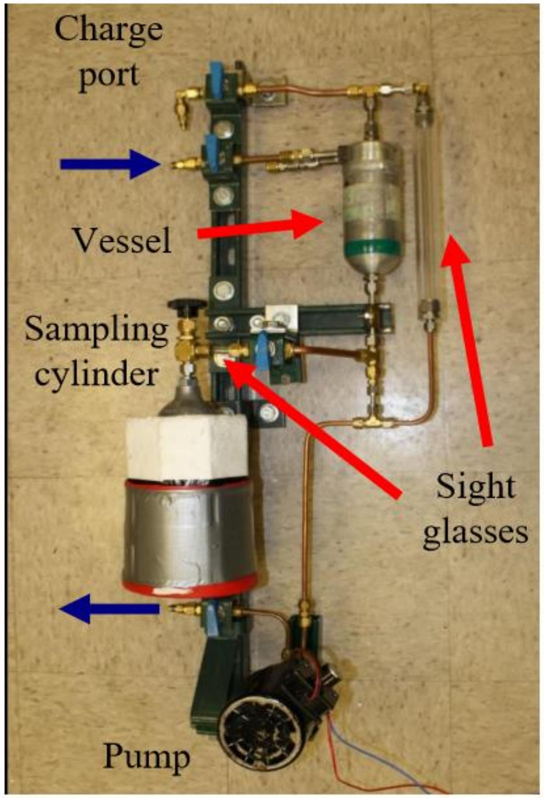
(Image credit: Dr. Yatim)

Sampling Method

$$\omega = \frac{m_{oil}}{m_{oil} + m_{solvent}}$$

$$m_{oil,total} = \frac{\omega}{1-\omega} m_{solvent,total}$$

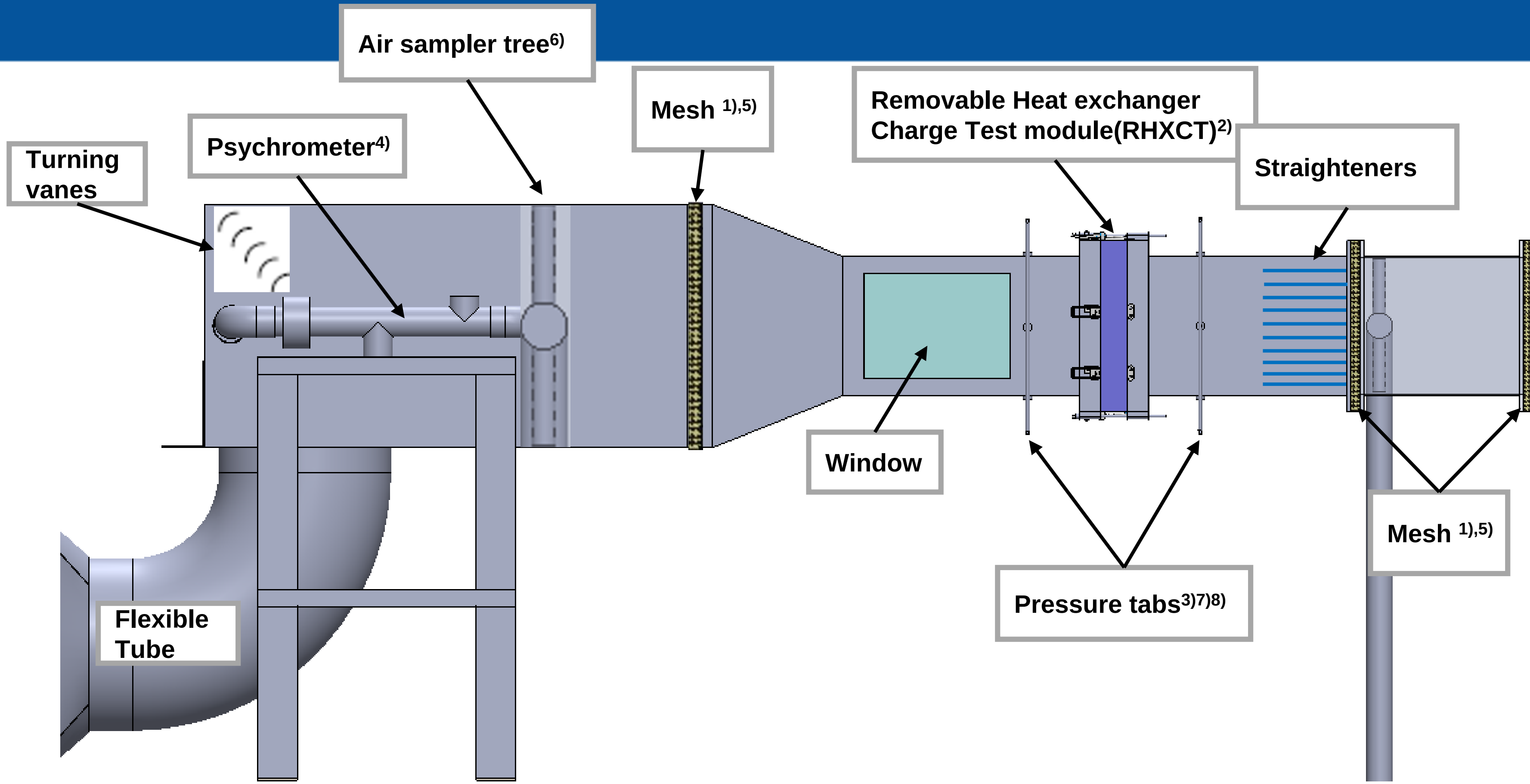




(Image credit: Dr. Jin)

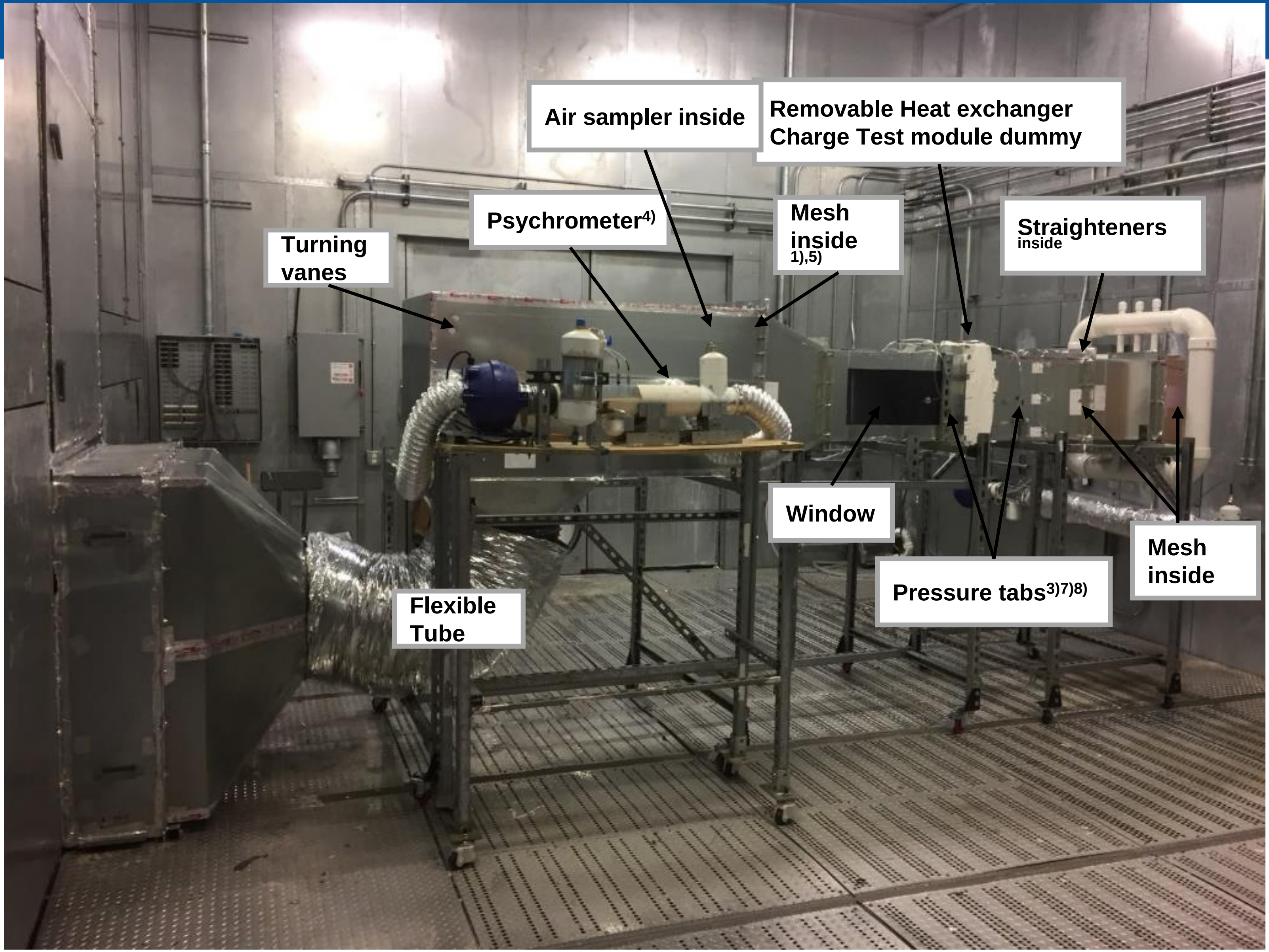
Figure 2. 6 Mix and sample device (MSD)

Schematic Diagram of Duct

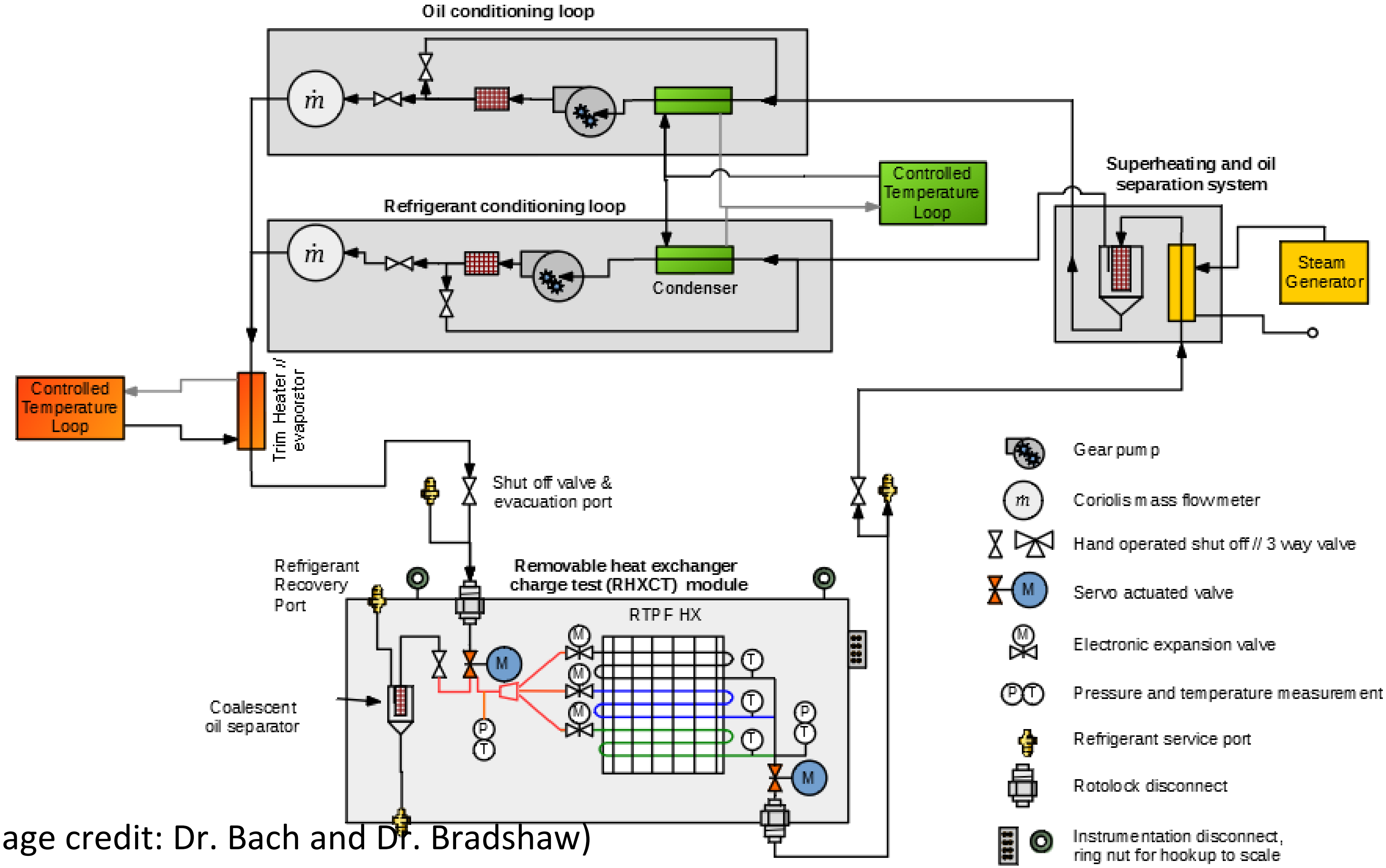


1) ASHRAE STANDARD41.2: Distance from mesh to mesh
2) ASHRAE STANDARD37: 1.5x(Duct width x Duct height)$^{1/2}$=25", Distance from mesh to coil
3) ASHRAE STANDARD41.2: 0.5x(Duct width x Duct height)$^{1/2}$=8.4", Distance from coil to pressure tab
4) ASHRAE STANDARD41.2(1986) Figure15: Distance from coil to air sampling tree
5) ASHRAE STANDARD41.2: open area 50~60% are suggested.
6) ASHRAE STANDARD41.1: Air sampling device design reference
7) ASHRAE STANDARD41.2: static pressure tabs
8) ASHRAE STANDARD37: connection for pressure tabs

Duct for Indoor Coil1 Complete

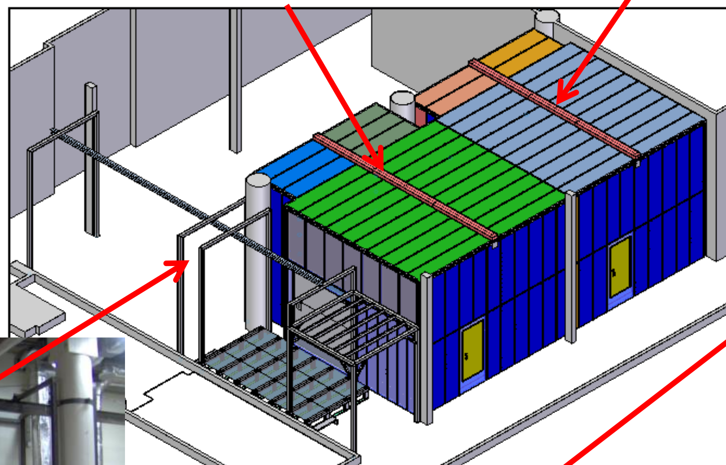


Ref. + Oil loops

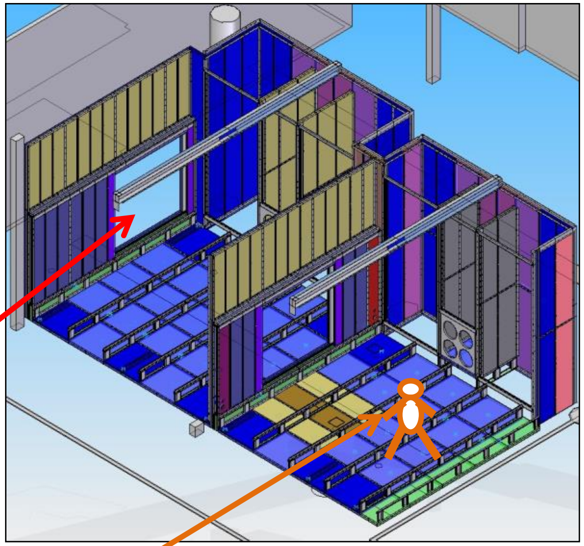


(Image credit: Dr. Bach and Dr. Bradshaw)

Experimental facility: New Large Scale Climate Control Psychrometric Chamber (2007 to 2010; slide credit: Dr.Cremaschi)



Open cut out of the chamber



Mezzanine and heavy duty gantry crane

Product flow in/out door

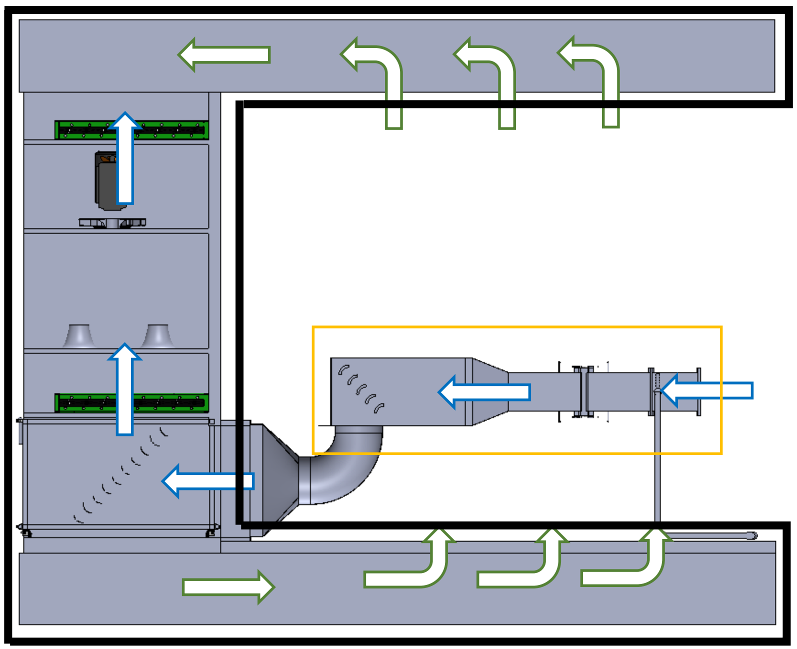
Section of the Indoor room

Indoor and outdoor rooms

- 20 tons of refrigeration
- The outdoor room: -40°F to 130°F
- The indoor room: 55°F to 130°F

Psychrometric Chamber

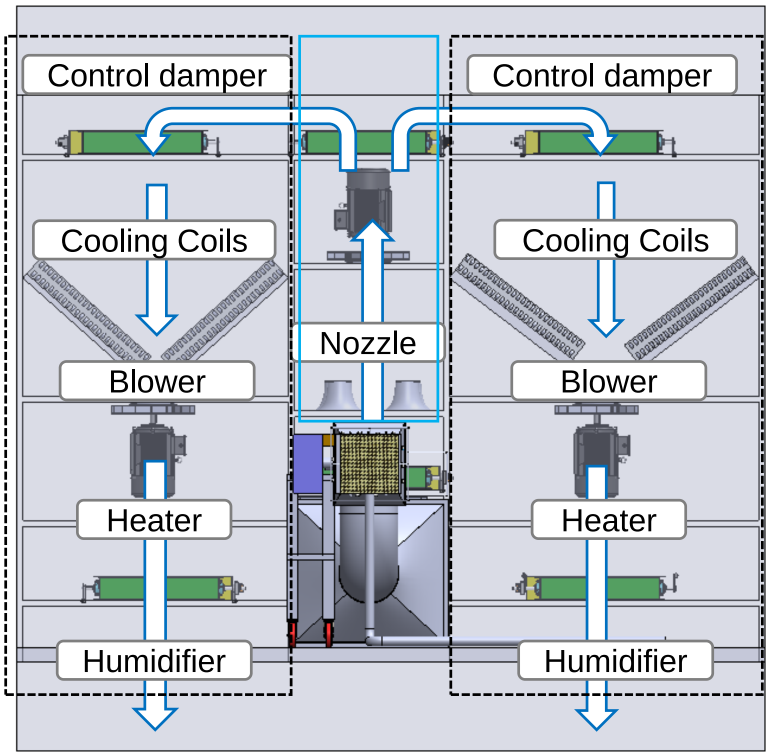
Side View



Setup

Chamber

Front View



Flow measurement

Conditioning loop

1) Max.capacity: 15tons(52.7kW), Max. airflow rate(8000cfm)

Test Conditions

Table 7: Condenser Mode Test Conditions (1785-TRP's Table 1)

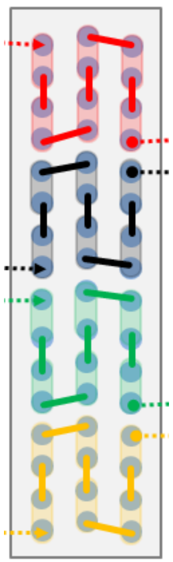
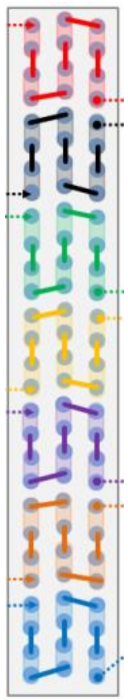
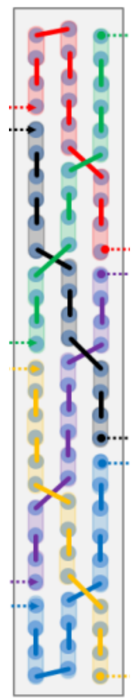
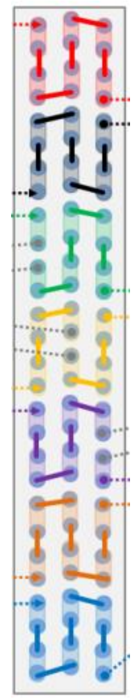
Condenser Independent Variables		Indoor Coil (HP)	Outdoor Coil (AC)
Airflow	CFM	As required	As required
Inlet Superheat	(R)	30-60	30-60
Liquid temperature	(°F)	90-100	100-110
Refrigerant Flow	lb/hr	100, 300, 400	150, 350, 500
Air Inlet Temperature(s)	(°F)	70/60	95/75

Table 8: Evaporator Mode Test Conditions (1785-TRP's Table 2)

Evaporator Independent Variables		Indoor Coil (AC)	Outdoor Coil (HP)
Airflow	CFM	As required	As required
Reference liquid temperature	(°F)	100-110	90-100
Outlet superheat	(R)	5-20	5-20
Refrigerant Flow	lb/hr	150, 350, 500	100, 300, 400
Air Inlet Temperature(s)	(°F)	80	47

(Image credit: Dr. Bach and Dr. Bradshaw)

Coil circuit

IC1	IC2	IC2-INTERLACED	IC2-SUBSECTION
			

OC1	OC2	OC3