# Effect of Inlet Duct and Damper Design on Fan Performance and Static Pressure Measurements (ASHRAE RP 1743)

Md Yeam Hossain
*Oklahoma State University, United States of America*, yeam.hossain@okstate.edu

Christian K. Bach
*Oklahoma State University - Main Campus*, cbach@okstate.edu

Omer San
*Oklahoma State University, United States of America*, osan@okstate.edu

# Effect of Inlet Duct and Damper Design on Fan Performance and Static Pressure Measurements (ASHRAE 1743 RP)

Md Yeam Hossain[1*], Christian Konrad Bach[2], Omer San[3]

Oklahoma State University, Department of Mechanical and Aerospace Engineering
[1]Contact Information: Phone-405-269-7572, E-mail-yeam.hossain@okstate.edu
[2]Contact Information: Phone-405-744-5916, E-mail- cbach@okstate.edu
[3]Contact Information: Phone-405-744-5900, E-mail-osan@okstate.edu

* Corresponding Author

## ABSTRACT

ASHARE and AHRI provide various standards for designing a test setup for HVAC systems, albeit with limited detail for the inlet ductwork design. The purpose of this study is to develop an inlet duct design guideline for inclusion in the AHRI and ASHRAE testing standards that reduces the risk of false testing failures and will lead higher integrity of the testing results at different laboratories. False testing failures in this context are differences between measured performance data by third party accreditation laboratories relative to a manufacturers own laboratory that exceed the allowable tolerances given in the applicable standards and are caused by reasons that are unrelated to the actual performance of the equipment. Such reasons include differences in the inlet ductwork that will affect the equipment's fan performance.

This study will evaluate the performance of the fan of the indoor air handler of split systems for various design parameters including the fan and motor type of the air handling unit, inlet duct and damper configurations and air flowrate through the unit. Fan power consumption and air flowrate of the system are to be determined for a range of static pressures for different inlet duct/damper configurations.

The test plan includes indoor air handlers of 1.5-ton, 3-ton and 5-ton capacity of several manufacturers. It additionally includes furnace and coil. For the air handling unit's fans three types of motors and two types of fan configurations are considered. Static pressures will be measured between the inlet and outlet of the air handler. Finally, the experimental results will be used to validate future CFD simulations of the inlet ductwork.

## 1. INTRODUCTION

The American Society of Heating, Refrigerating and Air Conditions Engineers (ASHRAE) describes the test procedures of unitary air conditioning and heat pump equipment in ASHRAE Standard 37 (ASHRAE, 2009), *Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment*. The standard describes the construction of the inlet and outlet plenums and specifies the minimum length required for the inlet and outlet plenums to accurately measure the static pressure across the unit. The standard requires an outlet plenum for the testing purpose and merely recommends installing an inlet plenum if space allows.

According to ASHRAE TRP 1743, recent regulatory changes (DOE, 2017) require the use of an inlet ductwork during testing of furnaces and indoor air handling units (AHUs). However, if units are tested in vertical orientation, then height limitations of manufacturer's and third-party testing facilities may prohibit the use of ductwork of sufficient length. That may lead them to compromise with the standard and in result will reduce the reliability of test facilities results. ASHRAE 1743 RP will investigate the effect of alternative inlet ductwork onto fan performance and recommend alternate shorter inlet ductwork that leads to minimal changes in fan performance relative to the ASHRAE 37 (ASHRAE, 2009) standard inlet plenum length.

To accomplish the project our goal is to test AHUs and furnaces of different tonnage capacities and types. For the project we will test units of 1.5-ton (5.3 kW), 3-ton (10.6 kW), and 5-ton (17.6 kW) capacity. For each unit size, blow through and draw through type fan configuration will be tested. Units that use fans with Electronically Commutated Motor (ECM), Constant Torque Motor (CTM), and Permanent Split Capacitor (PSC) motor will be tested. Our focus will be on the 3-ton units, where tested units include all three types of motors. 1.5-ton (5.3 kW), and 5-ton (17.6 kW) capacity units will be considered with the increasingly used ECM configuration of the fan motor.

The tests will be conducted at the fan setting that results in a flowrate close to 350 cfm/ton (0.047 $m^3$/s/kW) (low), and 450 cfm/ton (0.06 $m^3$/s/kW) (high) air flowrate. A damper will be attached with the inlet plenum, as is the case for cyclic tests of AHUs. For the construction of the test setup, the minimum length of the inlet and outlet plenum are calculated based on the ASHRAE Standard 37 (Standard 37-2009) and Department of Energy Pt. 430, Subpt. B, App. M. (Hogan, 2015).

At the beginning, the AHUs and furnaces will be tested with the minimum length of inlet and outlet plenum, which will be considered as our baseline test. The static pressure across the units, velocity profile, power consumptions etc. will be measured. As our main goal is to investigate the effect of inlet ductwork, we will be changing the length of the inlet plenum to see the effect on the fan performance of the tested units. The data collected will be compared with that of from the base line test data. We will be reducing the length of the inlet plenum and see how much the result deviates from the base line results and then suggest alternate geometry if necessary. The overarching goal is to then develop inlet ductwork that is much shorter than the currently required minimum while resulting in comparable behavior to the baseline inlet duct that conforms to the minimum length requirements.

## 2. LITERATURE REVIEW

ASHRAE research project 1581 (Pate et al., 2016) similarly to RP 1743 addressed overall testing “stack” height of inlet duct – AHU – outlet duct during testing in vertical configuration. However, their focus was to investigate the effect of a reduction of outlet plenum length with the goal to maintain the reliability of ASHRAE Standard 37 (ASHRAE, 2009) testing method. Two approaches to accomplish that goal were employed. The first approach was to change the air flow direction after the AHU outlet from vertical to horizontal, substantially reducing the height of the test apparatus. This was accomplished using an elbow at the unit outlet and placing the outlet duct in a horizontal position. Secondly, they reduced the height of the outlet duct by inserting a passive resistive device between the unit and the static pressure measurement location.

Testing of AHUs requires accurate measurements of external static pressure and air flowrates since both variables affect the performance and power consumption of the unit’s fan. ASHRAE Standard 37 (ASHRAE, 2009) establishes a uniform method for testing unitary air conditioning and heat pump equipment and specifies how to measure static pressure and air flow. Minimum inlet and outlet plenum length are specified based on the tested AHU’s inlet and outlet cross section. However, ASHRAE (2009) does not strictly require the use of an inlet plenum if the available space does not permit its use. ASRHRAE (2009) also includes the specifications for the air flowrate measuring apparatus commonly known as code tester or flow measurement nozzle box.

According to the above ASHRAE standard, installation of an inlet plenum is not required but recommended if the space in the indoor room permits. However, recent regulatory changes in the US lead to the requirement specified in DOE (2017) of an inlet plenum with specific length requirements. DOE (2017) also requires adding a mechanical damper at the inlet of the inlet plenum for cyclic testing.

ANSI/AHRI Standard 210/240 (Standard, 2008) specifies the operational conditions for indoor and outdoor units. Air inlet conditions to the indoor and outdoor unit are specified in terms of target dry bulb and wet bulb temperature. Additionally, test operating and condition tolerances for nozzle pressure drop, external voltage, external resistance to airflow and temperatures are specified to ensure sufficient quality of the obtained performance date. A minimum external static pressure to be maintained across the test units of different nominal cooling or heating capacity. However, this requirement of external static pressure differs from the updated DOE requirements (DOE, 2017). DOE recommends external static pressure (Implementation date January 1, 2023) higher than the ANSI/AHRI Standard, e.g. 0.50 w.c. (water column; 124.42 Pa) for 3-ton split systems instead of 0.15 w.c. (37.33 Pa) as given in ANSI/AHRI 210/240 Standard.

## 3. EXPERIMENTAL SETUP AND TEST CONDITIONS

The test conditions for the ASHRAE-1743 research project are selected according to the ANSI/AHRI Standard 210/240 (ANSI/AHRI Standard 210/240, 2008) and ANSI/ASHRAE Standard-116-2010 (Table-6a) (ANSI/ASHRAE Standard 116,2010). For the test conditions the external static pressure, dry and wet bulb temperature and test tolerances are considered. All the test conditions are selected for cooling test and indoor unit only. **Figure 1** shows the minimum external static resistance required by DOE and ASHRAE standard for different units and the test conditions for our experiment.

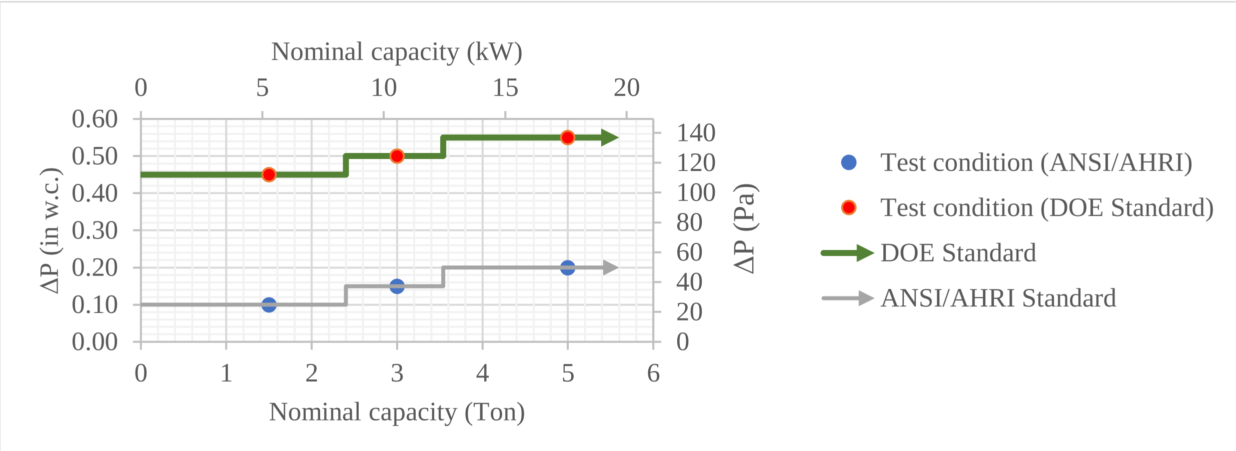
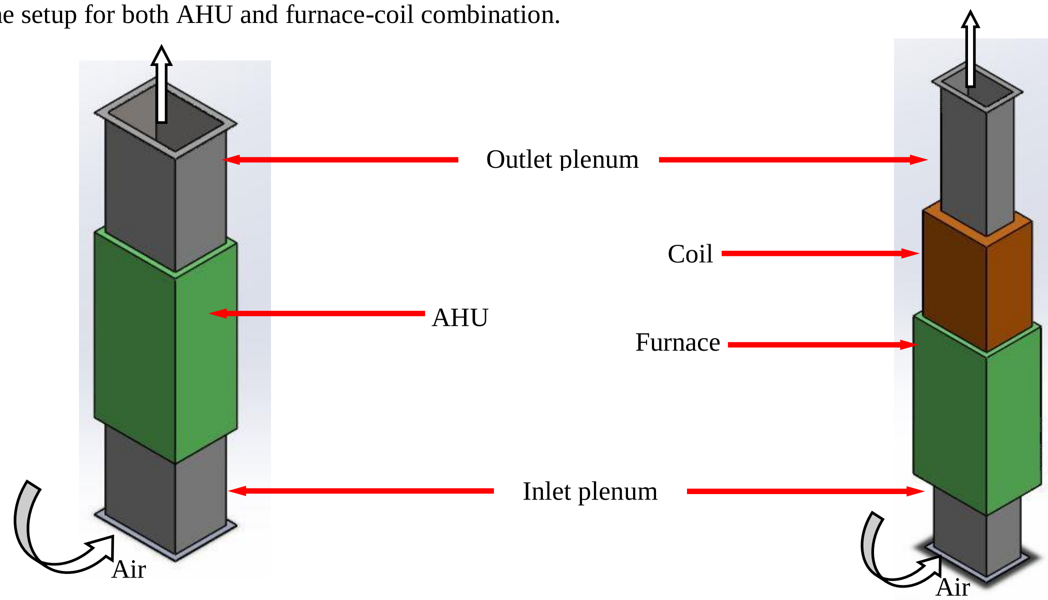



**Figure 1:** Minimum external resistance with test conditions used in the project

### 3.1 Test setup design

For our experiment we have both AHU's and furnaces. For furnaces a coil will be mounted at the top of the furnace. For the AHU's, the equipment outlet and inlet cross-sectional areas are considered for evaluating the minimum length of outlet and inlet plenum. In case of furnace and coil combinations, the minimum outlet and inlet plenum length is calculated using the cross-sectional area of coil outlet and furnace inlet respectively. **Figure 2** shows a schematic of the setup for both AHU and furnace-coil combination.




**a)** Inlet and outlet for AHU

**b)** Inlet and outlet for furnace-coil

**Figure 2:** Schematics of the inlet and outlet plenum for test units

### 3.2 Unit test matrix

**Table 1** shows the different units (AHUs and furnace-coil combinations) with their motor type and fan configuration as well as the low and high air flowrates closest to the target low/high flowrates of 350 cfm/ton-450 cfm/ton. The basis of selecting the units were mainly the motor type, fan configuration and the range of air flowrate provided. AHUs and furnace-coil combinations were selected to include different motor types and fan configurations, as well as a wide variety of manufacturers. This resulted in units of blow and draw through fan configuration and of motor types ECM, PSC, and CTM.

The focus is on 3-ton (10.6 kW) units, for which we have selected both AHUs and furnace-coil combinations for all three types of motors and for both fan configurations. In case of the 1.5-ton (5.3 kW) unit a CTM draw through type configuration will be tested. The 5-ton (17.6 kW) units cover both blow and draw through configurations with ECM driven fans.

**Table 1:** Unit test matrix

<table>
<tr><th>Nominal Capacity [tons]</th><th>Motor Type</th><th>Fan Configuration</th><th>Type</th><th>Cooling air flowrate low (cfm/ton)</th><th>Cooling air flowrate high (cfm/ton]</th></tr>
<tr><td rowspan="2">5</td><td rowspan="2">ECM</td><td>Blow</td><td rowspan="2">AHU</td><td>292</td><td>447</td></tr>
<tr><td>Draw</td><td>340</td><td>420</td></tr>
<tr><td rowspan="8">3</td><td rowspan="3">ECM</td><td rowspan="2">Blow</td><td rowspan="2">Furnace and coil</td><td>290</td><td>450</td></tr>
<tr><td>290</td><td>445</td></tr>
<tr><td>Draw</td><td>AHU</td><td>230</td><td>491</td></tr>
<tr><td rowspan="2">CTM</td><td>Blow</td><td>Furnace and coil</td><td>260</td><td>435</td></tr>
<tr><td>Draw</td><td rowspan="3">AHU</td><td>316</td><td>448</td></tr>
<tr><td rowspan="3">PSC</td><td>Blow</td><td>322</td><td>417</td></tr>
<tr><td rowspan="2">Draw</td><td>345</td><td>498</td></tr>
<tr><td>AHU</td><td>353</td><td>405</td></tr>
<tr><td rowspan="2">1.5</td><td>ECM</td><td rowspan="2">Draw</td><td rowspan="2">AHU</td><td>310</td><td>460</td></tr>
<tr><td>CTM</td><td>338</td><td>484</td></tr>
</table>

### 3.3 Plenum length calculation

Equations **(1)** and **(2)** specify the minimum length of inlet and outlet plenums. These equations are based on the ASHARE 37 standard (Standard A. S., Standard 37-2009), which is referred to as a mandatory reference by DOE (Hogan, 2015). **Table 2** gives the overall calculation of the length of the plenums for the selected units. Initially the test units' plenums will be constructed with the minimum ASHRAE 37 lengths for our baseline tests. Baseline test results will then be compared with other inlet duct designs. ASHRAE Standard 37 (Standard, 2009) specifies the outlet and inlet plenum dimensions and it gives the formulae for the minimum plenum lengths, which are also used for this project. For the outlet plenum, the minimum required length is,

$$L_{min,out} = 2.5\sqrt{AB}, \quad (1)$$

where,
*AB*= Cross-sectional area of the equipment outlet.

Similarly, the minimum inlet plenum length is defined as

$$L_{min,in} = 1.5\sqrt{CD}, \quad (2)$$

where,
*CD*= Cross-sectional area from the equipment inlet.

**Table 2:** Minimum inlet and outlet plenum length calculation

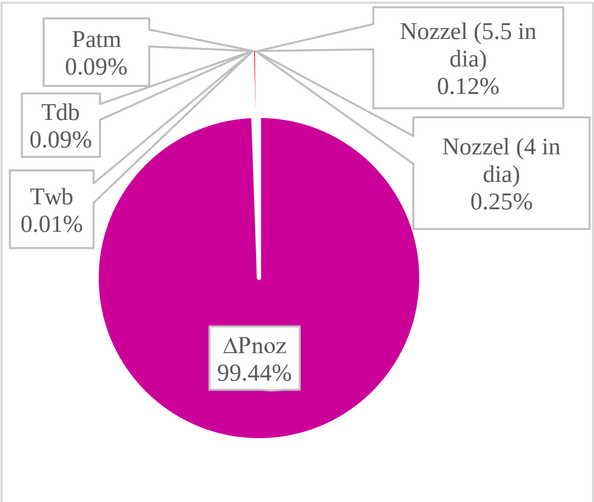
| **Test Unit Code**<br><br>**Capacity[tons]-Motor Type – Fan Location [B=Blow through, D=Draw Through]** | **Height** | **Top Outlet** | **Minimum Outlet Plenum Height required** | **Bottom Inlet** | | | **Minimum Inlet Plenum Height required** |
|---|---|---|---|---|---|---|---|
| | **in** | **Width (A) in** | **Depth (B) in** | **in** | **Width (C) in** | **Depth (D) in** | **in** |
| 5-ECM-B | 61.70 | 14.35 | 20.50 | 42.88 | 20.50 | 17.15 | 28.13 |
| 3-PSC-B | 55.70 | 14.35 | 18.40 | 40.62 | 18.40 | 17.15 | 26.65 |
| 3-ECM-D | 52.00 | 13.00 | 20.00 | 40.31 | 18.28 | 17.41 | 26.76 |
| 3-PSC-D | 51.00 | 19.75 | 11.06 | 36.95 | 21.00 | 20.00 | 30.74 |
| 3-PSC-D | 46.00 | 13.00 | 16.50 | 36.61 | 18.28 | 13.91 | 23.92 |
| 3-ECM-B | 40.00 | 19.63 | 19.75 | 48.20 | 23.50 | 19.50 | 32.11 |
| Coil for 3-ECM-B | 30.06 | 19.25 | 19.31 | | | | |
| 3-CTM-B | 33.00 | 16.38 | 19.44 | 44.16 | 23.50 | 16.00 | 29.09 |
| Coil for 3-CTM-B | 27.50 | 16.00 | 19.50 | | | | |
| 1.5-ECM-D | 45.25 | 11.06 | 14.75 | 31.93 | 19.00 | 15.00 | 25.32 |
| 1.5-CTM-D | 42.69 | 12.44 | 11.00 | 29.24 | 12.31 | 19.81 | 23.43 |
| 3-CTM-D | 49.63 | 19.25 | 11.00 | 36.38 | 19.13 | 19.81 | 29.20 |
| 5-ECM-D | 59.19 | 22.75 | 11.00 | 39.55 | 22.69 | 19.81 | 31.80 |

### 3.4 Preliminary uncertainty analysis

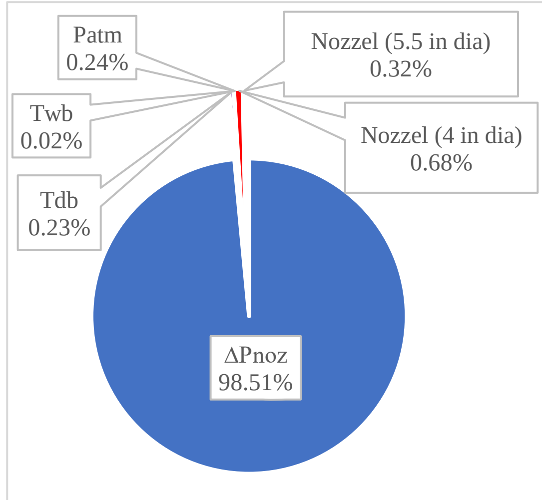
A preliminary uncertainty analysis was completed to estimate the accuracy of the air flowrate measurement in the experiment. **Table 3** shows our results of that uncertainty analysis for the units at different flowrates. Furthermore, **Table 4** shows a list of instruments that have been selected for this project. Instruments nominal range and uncertainty is given in the table. This uncertainty analysis is done based on the measurement uncertainty of the instruments selected for the project. Nozzle sets of the code tester for each unit at the two desired nominal flowrates (low = 350 cfm/ton and high = 450 cfm/ton) were selected to minimize measurement uncertainty. The selected nozzle sets maintain the velocity range across the nozzles, which is 15 m/s to 35 m/s, as required by ASHRAE Standard 37-2009. The uncertainty analysis allowed the evaluation of the effect of different instrument parameters. The results show that the differential pressure measurement across the nozzles has, with 96% to 99%, the highest contribution to the uncertainty of the airflow measurement. **Figure 3** shows a graphical representation of different properties contribution in uncertainty measurement of air flow for the case of 3-ton unit at 350 cfm/ton and 450 cfm/ton.

**Table 3:** Uncertainty calculation

| **Nominal capacity [Tons]** | **Nominal flowrate [cfm/ton]** | **Desired flowrate [cfm]** | **Calculated flowrate [cfm]** | **Uncertainty of air flowrate [%]** | **Differential pressure [inch w.c.]** | **Nozzles used [diameter in inches]** |
|---|---|---|---|---|---|---|
| 1.5 | 350 | 525 | 523 | 0.33 | 0.95 | 3,4 |
| | 450 | 675 | 675 | 0.20 | 1.58 | |
| 3 | 350 | 1050 | 1053 | 0.50 | 0.62 | 4,4,5.5 |
| | 450 | 1350 | 1352 | 0.31 | 1.02 | |
| 5 | 350 | 1750 | 1756 | 0.40 | 0.78 | 4,4,5.5,5.5 |
| | 450 | 2250 | 2251 | 0.25 | 1.28 | |




**a)** 3 ton at 350 cfm/ton




**b)** 3 ton at 450 cfm/ton

**Figure 3:** Contriution of properties in uncertainty

**Table 4:** Instrumentation list

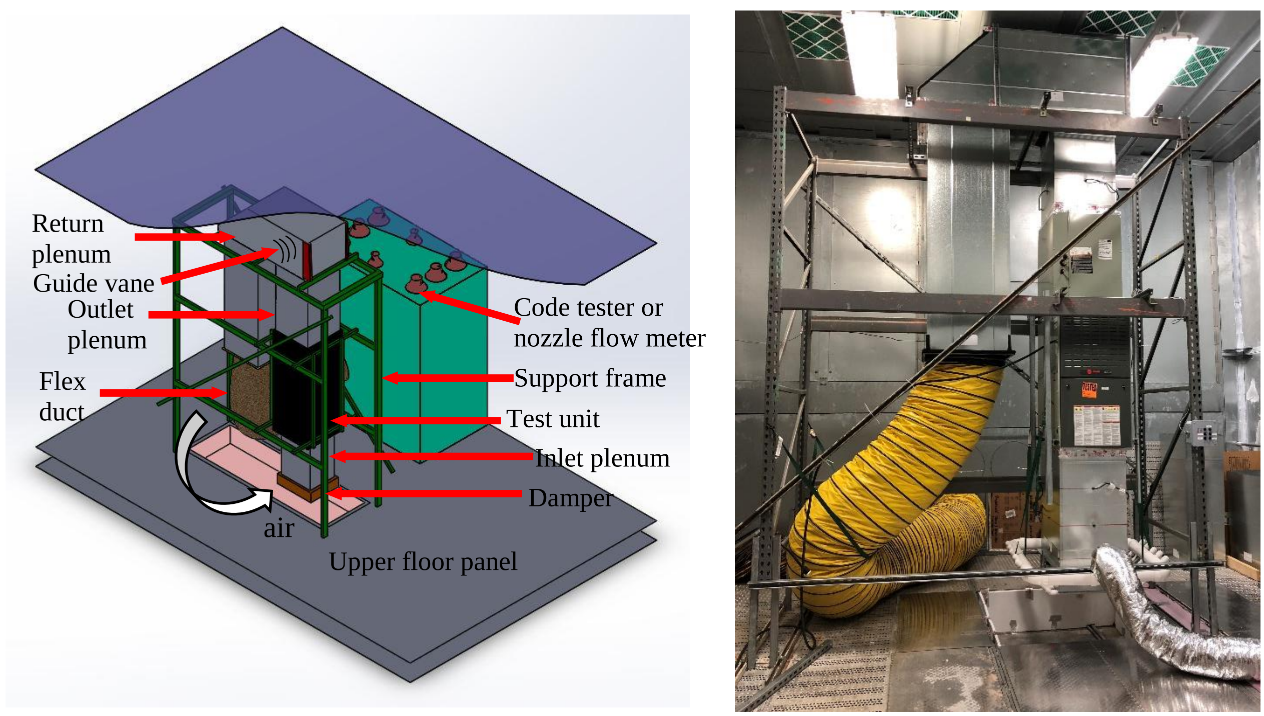
| Parameter | Manufacturer | Model | Nominal value | Uncertainty |
|---|---|---|---|---|
| Differential Pressure Across Nozzles | Setra | Model 264 | 0 to 2.5 in w.c. | ± 0.25% FS |
| Differential Pressure Across Unit | Setra | Model 265 | 0 to 0.5 in w.c. | ± 0.25% FS |
| Barometer | Vaisala | PTB110 | 0.002 to 0.004 in w.c. | ± 0.12 in w.c. |
| Pressure at Nozzle Inlet | Setra | Model 266 | -1.5 to 1.5 in w.c. | ± 0.25% FS |
| Unit Supply Dry Bulb RTD | Omega | PR-10 | 5 to 140 (°F) | ±0.2 (°F) |
| Unit Supply Wet Bulb RTD | Omega | PR-10 | 5 to 140 (°F) | ±0.2 (°F) |
| Electrical Power (45-65 Hz) | Camille Bauer Metrawatt AG | APLUS 2111-0E1 | Adjustable using the current transformer | ± (0.02% FS + 0.08% Reading) |
| Electrical Voltage | Camille Bauer Metrawatt AG | APLUS 2111-0E1 | 57.7-400 $V_{LN}$ | ± (0.02% FS + 0.08% Reading) |
| Electrical Current | Camille Bauer Metrawatt AG | APLUS 2111-0E1 | 1-5 Amp<br>Max 7.5 Amp | ± (0.02% FS + 0.08% Reading) |
| Current Transformer | Ohio Semitronics | Model-12974 | Current Ratio: 150:5 | ± 0.3% FS |
| Humidity Sensor | Omega | HX71-MA | 15% to 85% | ± 4% RH |

## 4. EXPERIMENTAL SETUP DESIGN

**Figure 4** shows the experimental setup design for this project. The experiment will be conducted at the psychrometric indoor chamber of Oklahoma State University. ASHRAE and ANSI/AHRI standard specified dry (80˚F) bulb temperature will be maintained throughout the experimentation. But the wet bulb temperature (67°F) will be adjusted to keep the air density constant throughout the experiments of different units. The return plenum will be supported by unistrut on top of the support frame. The outlet plenum of the tested unit will be connected at the right side of the plenum outlet box.

With that test unit, a damper will be connected at the end of the inlet plenum. A guide vane inside the plenum outlet box will redirect the flow after it exits the unit's outlet plenum. At the left side of the outlet plenum box there will be a duct connected with which a flex duct will be attached. The flex duct will then connect to the code tester (nozzle flow meter) at the back of the setup. To make the support frame stiffer, two cross beams are used at front and back of the frame. The plenum outlet box and the units are also supported at top and vertically respectively with unistrut, which is screwed with the unit and return plenum from two sides and at the bottom for the return plenum. For the units to be suspended vertically a rectangular frame has been made with unistrut and at the bottom the unistrut is screwed with the unit from two sides.

Most of the units can be tested in the psychrometric rooms without modifications. However, there is one-unit configuration that requires additional length. For that unit, two floor panels in the psychrometric indoor chamber are removed to provide an additional length of ~1 ft (0.3048 m) space at the bottom of the inlet plenum. Quantitative measurement of the airflow will be implemented at various heights of the inlet duct.




**a)** Experimental setup design **b)** Current setup

**Figure 4:** Test setup design

## 5. TEST PLAN

The goal of this project ASHARE 1743 is to suggest an alternate shorter inlet plenum that leads to negligible differences in air flowrate and fan power consumption relative to the standard length of inlet plenum required by US DOE (Hogan, 2015). To accomplish this goal, we decided to conduct the experiment with several configurations of the inlet plenum. Firstly, we will test the units (AHUs and furnace-coil combinations) with inlet plenums of the minimum required length. This test will be considered as our baseline test and will be according to ASHRAE and DOE standards. For the base line test the ducts will be made of sheet metal. Next the same baseline will be performed again, but this time the inlet plenum will be made of cardboard. For the next test configurations, the plenums will be made of cardboard with identical configuration, a practice that appears to be common in industry. Our next test plans include testing the units (AHUs and furnace-coil combinations) with

- Reduced inlet plenum length,
- No inlet plenum, and
- Guide vane installed at the inlet of the unit

**Figure 5** to **Figure 9** shows some schematics of our preliminary test plans. **Figure 5** and **Figure 6** shows the baseline tests with inlet plenums of sheet metal and cardboard. **Figure 7** is the test plan with reduced inlet plenum length. **Figure 8** is the test plan without any inlet plenum and **Figure 9** is the plan with a guide vane at the bottom of the test unit's inlet.

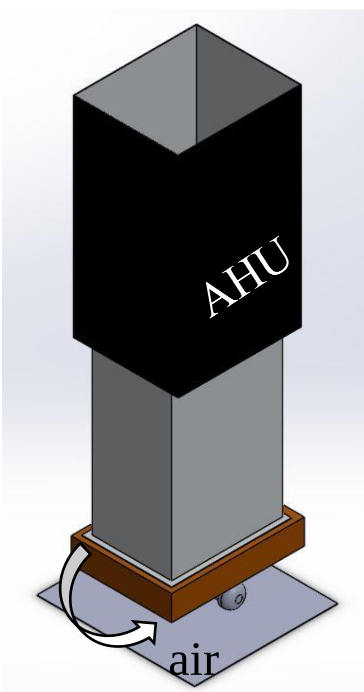



**Figure 5:** Configuration 1 DOE/ASHRAE compliant inlet duct (baseline test)

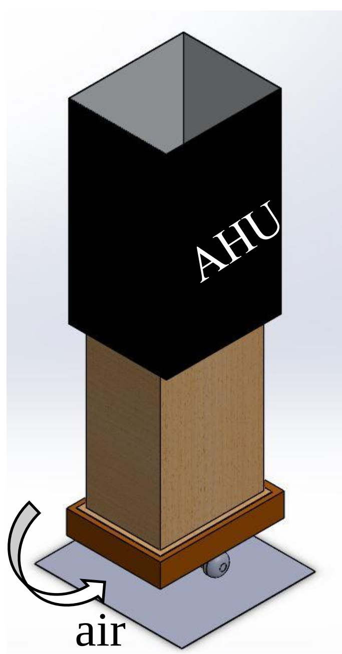



**Figure 6:** Configuration 1B Cardboard baseline duct

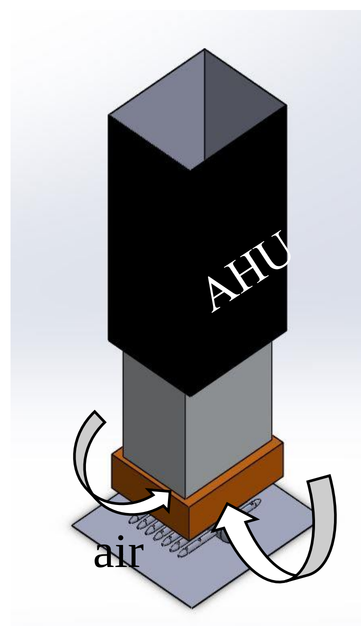



**Figure 7:** Configuration 2- reduced length of inlet plenum

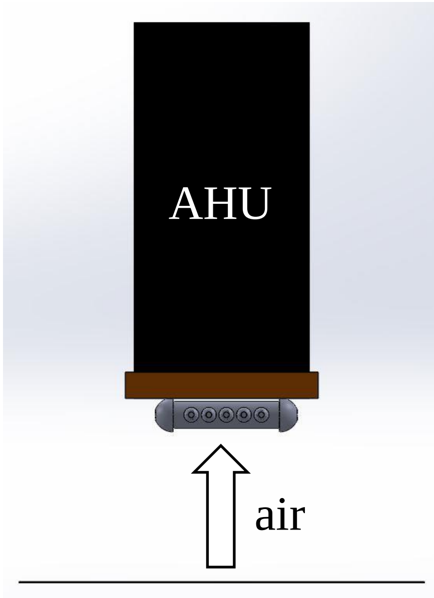



**Figure 8:** Configuration 3- no duct, no guide vane

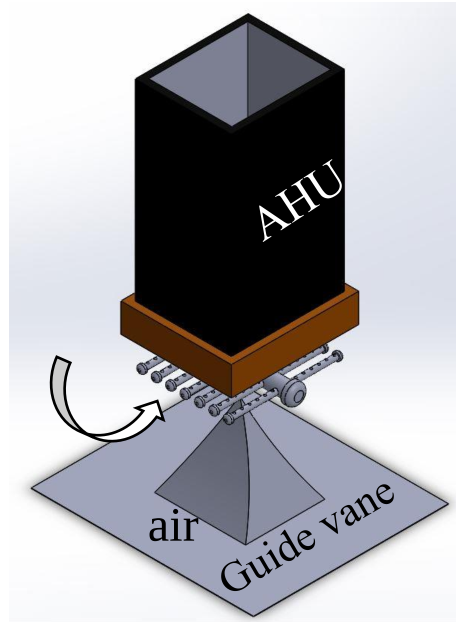



**Figure 9:** Configuration 4 - guide vane at inlet, no duct

## 6. SUMMARY AND FUTURE WORK

Status of the project is that we have completed the building of support frame and one of the 3-ton units is mounted vertically with the inlet and outlet plenums attached. We are also working on the air sampler design and construction. Along with that the instrumentation of the setup is going. The results from this experiment will be validated by a CFD simulation in our future work. Also, by the CFD analysis a variety of inlet setup could be tested and by comparing the results a better inlet plenum configuration could be achieved. A companion paper (ID 3586) addresses preliminary work on that subject. The main goal of this project is to make the inlet plenum shorter which will maintain the reliability of ASHARE and DOE standards. After completing the experiment with all the proposed test plans, some tests will be repeated for the validation of the previous test results. At the end of the experiment a guideline will be proposed based on the findings from this experiment which could help manufacturers reducing the height of the setup in the test room and will reduce the risk of false testing failures. Our test is confined to vertical ducts and flow only. Future work may extend to horizontal ducts and flow of air.

## NOMENCLATURE

*Tdb*- Dry bulb temperature
*Twb*-Wet bulb temperature
*ΔPnoz*- Differential pressure across the nozzles
*Patm*- Atmospheric pressure
*ECM*- Electronically commutated motor
*PSC*- Permanent split capacitor
*CTM*- Constant torque motor

## REFERENCES


ANSI/AHRI. 2008. *Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment.* ANSI/AHRI Standard 210/240-2008. Air conditioning, Heating and Refrigeration Institute, Arlington.

ASHRAE. 2009. *Methods of Testing for Rating Electrically Drive Unitary Air-Conditioning and Heat Pump Equipment.* ASHARE 37-2009, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA

ANSl/ASHRAE. 2010. *Methods of Testing for Rating Seasonal Efficiency of Unitary Air Conditioners and Heat Pumps.* ANSl/ASHRAE 116-2009, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA.

ANSl/AMCA Standard 201-16. *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA. Air Movement and Control Association International, Illinois.

ANSl/ASHRAE. 1987. *Standard Methods for Laboratory Airflow Measurement*. ANSl/ASHRAE 41.2-1987, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA

Department of Energy. 2017. *Energy Conservation Program: Test Procedures for Central Air Conditioners and Heat Pumps.* 10 CFR parts 429 and 430.

Pate, Michael, Joshua, Kading, & Wheeler, Grant (2013). *Develop Alternate Setup Guidelines for Unitary Air Conditioners which cannot Adhere to ASHARE 37/ ASHARE 116 Specified Duct Dimensions and External Pressure Tap Locations.* ASHRAE RP-1581.