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Tracer gas decay test in Net-Zero Energy Residential Test Facility

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MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Energy and Transportation Science Division

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1. Net-Zero Energy Residential Test Facility

The Net-Zero Energy Residential Test Facility (NZERTF) at NIST was built in 2012 to support the development and adoption of cost-effective net-zero energy designs, technologies, and construction methods (Fig. 1). It is two-story, and has four bedrooms, three bathrooms, and an open living room, dining room, and kitchen space. The NZERTF also has a basement and attic, both located within the conditioned space because the thermal and air-moisture barriers encompass the basement walls and attic roof. Transfer grilles link the living spaces to these two zones. The central heating and cooling system includes an air-to-air heat pump, which delivers air to the basement, first and second floors. The heat pump has a cooling capacity of 7.6 kW and a heating capacity of 7.8 kW. The indoor unit is in the basement and ductwork runs along the basement ceiling. A balanced heat recovery ventilator (HRV) is installed in the basement and has its own dedicated ductwork. The HRV supplies 47 L/s of outdoor air to the house, with supplies on the first floor (in the kitchen/dining area) and in each of the three second-floor bedrooms. Air from the first-floor bathroom and both second-floor bathrooms is returned to the HRV before being exhausted, though the HRV was turned off during the tests. The house also has a range hood exhaust and a clothes dryer exhaust, both of which were turned off for the tests. The temperature of the house was measured and the operation of the space conditioning system, including its recirculating air distribution fan, were controlled by a commercially available thermostat. Table 1 summarizes the characteristics of the NZERTF. Additional design, construction, equipment, and energy performance details for the NZERTF can be found in Refs. [1-3].

Fig. 1. Photograph of NZERTF.

Table 1. Characteristics of NZERTF.

Building characteristics	NZERTF
Year of construction	2012
Floor area (m^2)	245 (habitable area) 490 (all floors)
Building volume (m^3)	1301 (all floors)
Stories	3 above ground, includes attic
Height (m)	6.3
Exterior surface area, above grade (m^2)	367
ELA at 4 Pa (cm^2) (from blower door test)	137
Heating/Cooling system	Air-to-air heat pump 7.6 kW cooling capacity 7.8 kW heating capacity

2. Measurements

Tracer gas decay tests were conducted to measure decay rates in the NZERTF under the test conditions in **Table 2**. The mechanical ventilation system was off during the tests, as well as the dryer and range hood exhausts.

Table 2. Summary of test conditions.

Test code	Description	Testing dates	Internal loads
Test HEQ-N001	**Base Case (72F Setpoint)**	**Jan 12-18**	**None**
Test HEQ-N002	**Scheduled Internal Heat Gains**	**Jan 3-8**	**Saturday schedule**
Test HEQ-N003	**Demand Response (DR)-Enabled Thermostat**	**Jan 31-Feb 6**	**None**

The tracer gas decay tests complied with ASTM E741-11 [4], with sulfur hexafluoride (SF6) automatically injected every 72 hours at specified time intervals into the three bedrooms on the second floor and the kitchen on the first floor. Mixing fans were placed in the Living Room and at the top of the stairs to encourage mixing of air. The tracer gas was sampled in six locations (Master bedroom, Bedroom 3, Living Room, Basement, Attic, and Outside) in the NZERTF (Fig. 3) at 30 s intervals with a photoacoustic infrared sampler. This instrument has a measurement range of 3.6 mg/m3 to 35.8 mg/m3 (0.6 ppmv to 6 ppmv), and the manufacturer's reported accuracy is 5 % and its rated repeatability is within 1 %.

Fig. 2. Photoacoustic infrared sampler

During the tests, the basement and attic doors were always closed. Thus, the decay rates measured account for infiltration through the building envelope as well as any dilution (or addition) of SF6 from the basement or attic.

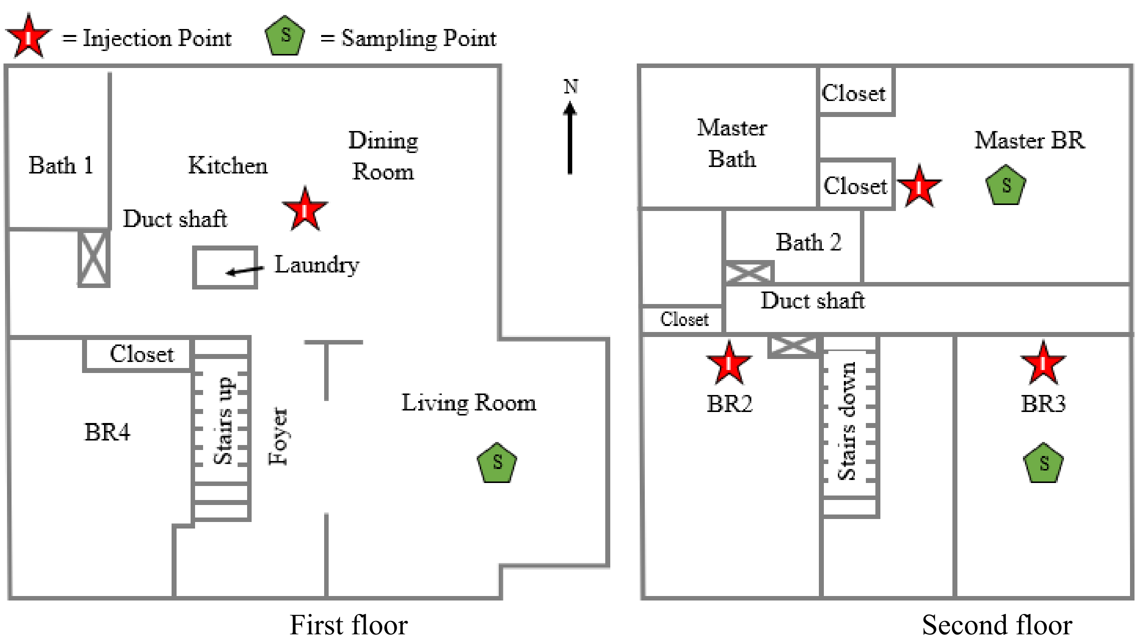

Fig. 3. SF_6 injection/sampling locations in NZERTF (sampling locations in Basement, Attic, and Outside not shown).

A summary of the measured decay rates is provided in **Table 3**The average outdoor temperature was lower than the average indoor temperature throughout all three tests. The infiltration increases as the average outdoor temperature decreases relative to the average indoor temperature. An increase in the average wind speed resulted in an increase in infiltration. The infiltration remained low throughout the series of tests.

Table 3. The average outdoor temperature was lower than the average indoor temperature throughout all three tests. The infiltration increases as the average outdoor temperature decreases relative to the average indoor temperature. An increase in the average wind speed resulted in an increase in infiltration. The infiltration remained low throughout the series of tests.

Table 3. Measured decay rates for NZERTF.

Test code	Average T_{out}-T_{in} (°C)	Average W_s (m/s)	Infiltration (1/h)	95 % confidence interval (1/h)
Test HEQ-N001				
Decay 1	-9.8	2.9	0.0339	0.0004
Decay 2	-13.7	2.3	0.0275	0.0002
Decay 3	-23.6	3.2	0.0433	0.0013
Test HEQ-N002				
Decay 4	-12.3	2.1	0.0246	0.0002
Decay 5	-18.6	2.4	0.0319	0.0002
Decay 6	-20.9	3.0	0.0386	0.0004
Test HEQ-N003				
Decay 7	-18.9	1.3	0.0313	0.0006
Decay 8	-10.8	2.2	0.0250	0.0003
Decay 9	-15.8	2.3	0.0314	0.0004

REFERENCES

[1] Pettit B, Gates C, Fanney AH, Healy W (2014) Design Challenges of the NIST Net-Zero Energy Residential Test Facility. (National Institute of Standards and Technology, Gaithersburg, MD).

[2] Fanney AH, Payne V, Ullah T, Ng L, Boyd M, Omar F, Davis M, Skye H, Dougherty B, Polidoro B, Healy W, Kneifel J, Pettit B (2015) Net-zero and beyond! Design and performance of NIST's Net-Zero Energy Residential Test Facility. *Energ Buildings* 101(0):95-109. https://doi.org/http://dx.doi.org/10.1016/j.enbuild.2015.05.002

[3] Fanney H, Healy WM, Payne V, Kneifel J, Ng L, Dougherty BP, Ullah T, Omar F (2017) Small Changes Yield Large results at NIST's Net-Zero Energy Residentail Test Facility. *Journal of Solar Energy Engineering*. https://doi.org/10.1115/1.4037815

[4] ASTM (2011)– *ASTM E741-11 Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution* (American Society for Testing and Materials, West Conshohocken, PA).