IAQ Specifications for a Netzero Energy Research Home

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Indoor Air Quality Specifications for a Netzero Energy Research Home

A Net Zero Energy Residential Test Facility (NZERTF) has been constructed at the National Institute of Standards and Technology in Gaithersburg, Maryland. The facility is currently being used to demonstrate that a home similar in size, aesthetics, and amenities to those in the surrounding communities can generate as much energy as it consumes on an annual basis, while meeting the needs of a family of four. The facility will subsequently serve as a test bed to facilitate the development and improvement of methods of test and performance metrics for existing and future energy efficiency technologies (1).The energy goals of the NZERTF are addressed by a combination of a well-insulated and airtight building envelope, efficient heating and cooling equipment, and the use of solar thermal and PV systems. In addition, ventilation and indoor air quality (IAQ) issues were addressed in the design of the building through a balanced mechanical ventilation system with heat recovery and detailed specifications for low-emitting building materials. A measurement program has been implemented to verify that the IAQ and ventilation goals are being achieved. These measurements include envelope airtightness, ventilation system airflow rates, thermal comfort, and the concentrations of volatile organic compounds (VOC) including aldehydes. This article describes the design of the building, with a focus on the ventilation and IAQ requirements, and discusses the measurements to verify that the ventilation and IAQ goals are being achieved.

Figure 1: Photograph of NZERTF

The NZERTF is located just outside of Washington DC, which has a climate characterized by hot and humid summers and mild winters. The mean temperatures in January and July are 2.2 °C and 26.7 °C respectively. The house itself is unoccupied and unfurnished, but it is configured to contain a family of four with devices to simulate their heat and moisture output as well as the operation of lights, appliances and typical plug loads. Note that airborne contaminants emitted by the occupants, such as carbon dioxide and particles, are not simulated.

The NZERTF was designed and constructed with the following objectives: (1) demonstrate net-zero energy over one year in a home that is typical for the surrounding community; (2) provide high-quality field measurements to validate and improve models of building energy use, equipment performance and environmental attributes; (3) serve as a test bed for measuring the performance of building components and systems; and, (4) improve laboratory test procedures for these components and systems to better predict whole building performance. The design principles for the facility were established early in the project and are as follows:

- building enclosure to minimize heat loss/gain
- locate all heating/cooling equipment within the conditioned space
- use energy efficient appliances and space-conditioning equipment
- design the house as a system, not as a collection of individual components
- meet energy requirements with renewables
- provide good IAQ.

It is the last principle, design for good IAQ, which is covered in this article.

As the building community pushes for buildings that use less energy and have reduced environmental impact, it is important to bear in mind that buildings are built for the occupants to live, work, learn and conduct other activities. Reducing energy use, to the detriment of the indoor environment, detracts from the real purpose of a building. Also, reduced productivity and higher health care expenses typically cost more than the savings from reduced energy use (2).

In order to provide a high-quality indoor environment within the NZERTF, two fundamental principles were employed: “Build tight, ventilation right” and contaminant source control. The first principle was pursued by constructing the building with a tight exterior envelope. While this approach is not new, particularly in northern Europe, the U.S. is still catching up with the latest airtightness construction practice (3). The goal for this house was that it be extremely airtight, for a U.S. home, through the use of a continuous air barrier system. Detailed specifications for the air barrier were developed by the design team with a goal that it have an air change rate of less than 1 air change per hour at 50 Pa as measured with a whole house pressurization test. The design team worked closely with the contractors to make sure they understood this goal and the envelope construction details required to make it happen. As part of this effort, quality control pressurization tests were performed during construction as shown in Figure 2.

Figure 2: NZERTF prepared for a quality control airtightness test (Note that windows openings are covered to measure tightness of only the opaque portions of the building envelope)

In order to ventilate right, the house was designed to comply with ASHRAE Standard 62.2-2010 (4). For this house, Standard 62.2 requires an outdoor air ventilation rate of 37 L/s as well as 25 L/s of continuous exhaust in each bathroom and 50 L/s of intermittent exhaust capacity in the kitchen. The whole house ventilation rate was provided with a heat recovery ventilator (HRV) that supplied air to the bedrooms and first floor living area and exhausted it from the bathrooms. The HRV does not provide for humidity transfer between the incoming and outgoing airstreams in order to better control the indoor humidity. The space conditioning system employs MERV 9 particle filters rated per ASHRAE Standard 52.2 (5), though Standard 62.2 only requires MERV 6 filters. In addition, the house was built to be resistant to radon entry consistent with local building codes.

In order to address the IAQ goals for the house, detailed specifications were developed for the materials used in its construction. These included limits on the VOC content of adhesives and sealants, attaching the interior wall board with mechanical fasteners instead of adhesives, requiring VOC emissions reports for insulation, and not allowing any added urea formaldehyde in the building materials. In addition, any substitutions suggested by the contractor were reviewed for their acceptability in terms of IAQ impacts.

These design goals and specifications were intended to provide a well-ventilated indoor environment with low contaminant levels (1). However, it is well known that design intent is not always realized in practice once a building is constructed and in operation. Therefore, a series of measurements are being performed in the house to verify its actual performance. These measurements include envelope airtightness, ventilation rates, thermal comfort, radon and VOC levels. Envelope airtightness was measured using a whole house pressurization test, which resulted in a value of about 0.6 air changes per hour at a pressure difference of 50 Pa. This is below the value in the house's design specifications and is very tight for U.S. homes.

Airflows are being measured in the HRV by performing air speed traverses with a hot wire anemometer in the four airstreams of the device: incoming outdoor air, supply air to the space, return air from the space, and exhaust air to the outdoors. Due to limitations in the ability to set the HRV fan speeds and flow rates, the actual airflow rate is roughly 47 L/s, which is about 20 % higher than the minimum requirement based on ASHRAE Standard 62.2. This flow rate has been measured approximately monthly since the house first became operational in late 2012. It was found that the airflow rate become significantly lower over time due to the clogging of the HRV filters with outdoor pollen and other substances. Since that time, the airflows are being measured weekly and the filter cleanliness is being closely monitored to avoid airflow reductions. It is important to note that such frequent monitoring of HRV operation in this research facility is unlikely to occur in an actual residence, leading to questions on how well such a device would perform in a more typical home.

Thermal comfort conditions are monitored in several rooms in the house to verify that the heating and cooling system is providing a thermally acceptable environment relative to the criteria in ASHRAE Standard 55 (6). This evaluation involves the measurement of dry-bulb temperature, relative humidity and radiant temperature using a gray globe as shown in Figure 3. These values are converted to predicted percentage dissatisfied (PPD) and predicted mean vote (PMV) and compared with the following criteria: PPD < 10 % and -0.5 < PMV < +0.5.

Radon concentrations have been measured over 3 to 5 days on four different occasions in 2013 to cover different seasons of the year. The measurements were made in the basement and on the first and second floors. All of the results were less than 37 Bq/m^3 in the living space, while the concentrations were on average below 82 Bq/m^3 in the basement. The level in the U.S., above which some remedial action is recommended, is 148 Bq/m^3 in occupied spaces in homes (7).

Figure 3: Test stand for measurement of thermal comfort parameters

VOC and aldehyde concentrations are being measured on an approximately monthly basis in the house to assess the impacts of the low-emissions material specifications. These measurements started in May 2013, with one-hour samples in the kitchen on the first floor, the second floor hallway and outdoors. The VOCs are collected on multi-sorbent sample tubes with 6 L sample volumes and analyzed using a gas chromatograph/mass spectrometer. Aldehydes are sampled using DNPH cartridges with 60 L sample volumes and analysis with a high-pressure liquid chromatograph. These results are still being analyzed, but it appears that some of the compounds have emission rates that increase with increasing outdoor temperature

This research effort shows the importance of airtightness, ventilation and IAQ in achieving high-performance, net zero energy buildings and demonstrates a detailed approach to achieving those performance goals. Future activities on the ventilation and IAQ performance of the NZERTF include a continuation of the monthly VOC and aldehyde sampling through the summer of 2014 to better understand the impacts of elevated temperatures on emissions. These results will be studied to understand which materials are associated with the emissions. In addition, the low-emitting material specifications used in the house will be converted into a format that will allow their use in other projects. A multizone building airflow model of the house was created in CONTAM (8). The model will be validated using tracer gas experiments in the facility and used to understand the impacts of different ventilation strategies and contaminant sources on IAQ and energy use.

References

(1) NIST, 2013. Net Zero Energy Research Test Facility. http://www.nist.gov/el/nzertf/index.cfm.

(2) Seppanen, O.A. and W. Fisk. 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research, 12 (4), pp. 957-973.

(3) Chan, W. R., J. Joh, and M.H. Sherman. 2012. Analysis of Air Leakage Measurements from Residential Diagnostics Database. LBNL-5967E. Berkeley, CA, Lawrence Berkeley National Laboratory.

(4) ASHRAE. 2010. ASHRAE Standard 62.2-2010 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

(5) ASHRAE. 2007. ANSI/ASHRAE Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

(6) ASHRAE. 2013. ANSI/ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

(7) EPA. 2012. A Citizen’s Guide To Radon. EPA 402/K-12/002, U.S. Environmental Protection Agency.

(8) Walton, G.N. and W.S. Dols. 2005. CONTAMW 2.4 User Guide and Program Documentation. NISTIR 7251. National Institute of Standards and Technology, Gaithersburg, MD. www.bfrl.nist.gov/IAQanalysis