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ORNL Building Technologies Research & Integration Center (BTRIC)
Existing Laboratory Facilities

Building 3144 Large Scale Climate Simulator

The **Large Scale Climate Simulator** provides controlled conditions of temperature and humidity above and below test sections as big as 12.5 ft by 12.5 ft. The assembled test section can weigh as much as 9000kg (10 Tons) and can be 1.8m (6 ft.) high. The large metered area allows actual roof details to be tested and the 1.8m (6 ft.) maximum height allows actual sloped assemblies to be constructed. For example, the effects of thermal bridging caused by wood or metal structural members in full-sized attics can be measured. The climate chamber simulates any outdoor condition of interest: steady-state temperatures from 65˚C to -40˚C (150ºF to -40ºF) and a wide range of relative humidities. Infrared lamps can heat surface temperatures to 93ºC (200ºF). The simulated outdoor conditions can be varied in diurnal cycles, facilitating dynamic response tests. The guard and metering chambers below the test section provide steady temperatures, controlled from 4˚C to 65˚C (40ºF to 150ºF), for guarded hot box tests in accordance with ASTM C1363. With the metering chamber lowered, relative humidities can be controlled in the guard chamber (used as a conditioning chamber) to simulate indoor moisture conditions. The apparatus is fully equipped with an automated data acquisition and process control system.

Building 3144 Rotatable Guarded Hot Box

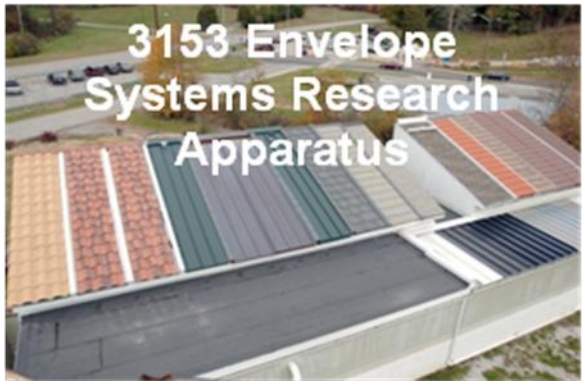
The ORNL **Rotatable Guarded Hot Box** is used to test full-size wall, fenestration, roof, and floor systems. This advanced thermal testing facility is designed in accordance with ASTM C1363, but has many features that go beyond the requirements of that standard. Few other hot box apparatus accept test specimens that are up to 4m by 3m (13 ft. by 10 ft.) in cross-section and up to 600mm (24 inches) thick. The metering chamber is approximately 2.4m by 2.4m (8 ft. by 8 ft.), accommodating the examination of a broad variety of specimen configurations. The test walls can be rotated and thermal performance measured at any angle from 0 to 180 degrees. The climate chamber temperature can be controlled from -23˚C to 60˚C (- 10ºF to 140ºF) and the air velocity from 0 mph to 15 mph. The metering chamber temperature can be controlled from 21 ˚C to 60˚C (70ºF to 140ºF) and air velocity from 0 to 1 mph. The test apparatus is fully instrumented and automated: the chamber

temperatures and air velocities are computer controlled at steady conditions or in 200 step cycles, which allows the system to be used to conduct dynamic guarded hot box tests needed to analyze massive wall systems.

Apparatus 3138 – Roof Thermal Research Apparatus

The **Roof Thermal Research Apparatus** was constructed to measure the effects of long-term weather exposure on small, low-slope roof test sections. The interior of the apparatus is heated and cooled to constant conditions year round and houses an automatic, continuous data acquisition system. The apparatus can handle up to 32 different instrumented 600mm by 600mm (2 ft. by 2 ft.) low-slope roof test sections at any one time. The long-term exposure tests have been of special interest for reflective roof coating and foam aging tests. The wall panels and slab-foundation edges of the building have also been used for long-term weather exposure tests.

Apparatus 3153 – Envelope Systems Research Apparatus



The **Envelope Systems Research Apparatus** (ESRA) is a one-level, air-conditioned test building that is oriented East/West for exposing large areas of low-slope and steep-slope roof products, including single-ply membranes, roof coatings, standing seam metal roofs, asphalt shingles, tile, and even photovoltaic panels. The facility also has exposure racks for weathering samples of roof materials. A solar reflectometer (ASTM C1549) and emissometer (ASTM C1371) are used to periodically measure the solar reflectance and thermal emittance of these samples. Work has moved from low-slope to steep-slope roof products. Several attic assemblies are now atop the ESRA for testing clay and concrete tile, asphalt shingles, and stone-coated metal roofs. The attic space beneath each test specimen is isolated to permit careful climate control and facilitate measurements of heat transfer through the individual roof systems. The ESRA can also be used to study energy and moisture flow through walls and foundations because two sides of the building are mostly below grade, while the other two sides are mostly above grade.

Basement of ESRA – Hygrothermal Materials Properties Laboratory and Insulation Materials Laboratory

The ESRA building also houses a **Hygrothermal Material Properties Laboratory** that consists of several experimental apparatuses. Three chambers are operated under controlled temperature and relative humidity. The temperature within the chambers can be maintained within the range of -15°C to 93°C (5°F to 200°F) with control within 0.5°C (1°F). For temperatures of 23°C (74˚F) and above, the relative humidity can be maintained within the range of 5% to 96% with control within 1% to 3%, depending upon the humidity level. Temperatures and humidities inside the chambers are monitored using precision platinum RTDs and chilled mirror hygrometers. The chambers are used for measuring the water vapor permeance of building materials (ASTM E96, both dry cup with a desiccant inside the cup, and wet cup with water inside the cup). The chambers also house a set of glass vessels that contain saturated salt solutions to obtain controlled relative humidities from 11% to 97%. These vessels are used to measure the sorption and desorption isotherms of building materials (ASTM C1498). A set of pressure plate apparatuses is used to measure the suction isotherm of building materials at very high (>95%) relative humidity. An apparatus for measuring liquid diffusivity consists of a water tank in which the bottom surface of a specimen can be brought into contact with the water surface. Two ovens are used to dry specimens to reference conditions prior to or after the other measurements. All property measurements are based on precision determinations of mass changes using a digital balance having a capacity of 5 kg (11 lbs.) and a resolution of 1 mg ($2.2*10^{-6}$ lbs.). The laboratory undertakes experiments that try to improve existing standards and develop those test methods where standards are lacking.

Also in the basement of ESRA is the **Insulation Materials Laboratory**, which is equipped to make precise measurements of the thermal and air-flow properties of thermal insulation materials and other building materials. Four heat flow meter apparatus (ASTM C518), of varying size and transducer arrangement, are available to measure steady state and transient heat flow of specimens up to 60 by 60 by 20 cm (24 by 24 by 8 inches). A permeability apparatus is used to measure resistance to air flow for fibrous insulation materials, an important property in determining insulation performance over a broad range of thicknesses and temperatures. A slicing machine is used to prepare thin slices of closed-cell foam insulation for accelerated aging experiments. There are 13 controlled-temperature chambers in this lab used to house long-term aging specimens: four freezers at -23˚C (-10°F), four refrigerators at 4˚C (40°F), and five heated chambers at 32˚C (90°F). Apparatus used to develop vacuum panel superinsulation are also available, including three air-tight chambers used to accelerate thin film laminate aging in controlled temperature environments filled with air, nitrogen, and helium at atmospheric pressure and an evacuation apparatus designed to permit internal panel pressure variation while the panel is within a heat flow meter apparatus.

Natural Exposure Test (NET) Facilities in Hot/Humid, Mixed/Humid, Cool/Humid and Cold/Humid Climates

For natural exposure tests (NETs) in challenging climates in addition to East Tennessee, ORNL has partnered with Washington State University (WSU), Weyerhaeuser Corporation, EIFS Industry Members Association, the Air Barrier Association of America, New York State Energy Research and Development Authority, and Syracuse University (SU) for NET research facilities in cool-humid, hot-humid, and cold-humid climates. The facilities are located respectively at the WSU Puyallup Research and Extension Center, on City of Charleston school property, and at SU. Agreements with the partners allow ORNL exclusive use of these facilities. In general the facilities are very similar in design. The purpose of the facilities is to expose test walls and roofs to the natural climate in that region. The buildings have a rectangular footprint with the long dimension oriented in the predominant rain direction. The interior of these facilities is temperature and humidity controlled and physically divided so that several different interior conditions can be evaluated simultaneously. The **Tacoma NET** has a rectangular footprint with 12 side-by-side wall bays on each side of the long dimension (24 wall bays total). The interior is temperature- and humidity-controlled and physically divided so that two different interior conditions can be evaluated simultaneously. The **Charleston NET** is similar to Tacoma except there are 15 side-by-side wall bays on each long side (30 wall bays total). The attic can also be divided to perform up to five different configurations simultaneously. The **Syracuse NET** resembles a small, two-story house. In place of windows, the NET has 34 bays total, on all four walls for testing. Each facility has over four hundred channels of data acquisition available and a meteorological data recording station. Typical measurements include moisture content of building materials, vapor pressure, temperature, heat flux, humidity, and condensation.

Building 3144 Equipment and Appliance Research Facilities

The experimental facilities used primarily for building equipment research are briefly described below.

The **Small Appliance Environmental Chamber** (10 feet x 10 feet x 8 feet) for testing single package appliances such as residential water heaters and refrigerators. This chamber can test over a temperature range of 0F – 120F and control humidity over a range of 40% to 80% RH at a cooling load of about 4,000 Btu/h. Utilities to the building include 480V, three phase at 225 A, with step-down transformers to provide 240v, 208 v and 120 v for testing appliances and equipment.

The **Mid-Sized Environmental Chambers**, feature both natural gas and electric utilities to support testing of gas heat pumps, electric heat pumps and air conditioners, gas/electric packaged units, refrigerators, desiccant systems, and small distributed generation/combined heat and power systems. Steady-state frosting/defrosting and cycling mode testing are conducted in accordance with applicable standards. The larger room has a 15 ft by 18 ft footprint, while the smaller room is 15 ft by 12 ft. The refrigeration system for these chambers can support up to 10 tons of cooling at an ambient temperature of 95°F. The refrigeration plant for this chamber can hold the temperature of the conditioned space at -20°F while supporting a 3-ton load with 300 cfm of laboratory make-up air injected into the system. Relative humidity can be controlled in each room over a 50-90% range. This ability to control wet-bulb (WB), dry-bulb (DB) and dew point (DP) is an important aspect of rigorous testing. The chambers are equipped with a process controller that monitors and controls all functions of the chamber's refrigeration and reconditioning plant, and a data acquisition system. Utilities to the building include 480V, three phase at 225 A, with step-down transformers to provide 240v, 208 v and 120 v for testing appliances and equipment.

The **Water Flow and Temperature Control Loop** is designed to provide water flow with fixed flowrate and temperatures to experiments. Flows up to 10 gpm can be maintained over a wide range of temperatures for testing appliances such as water heaters.

The **Water Heater Durability Test Facility** is capable of simultaneously testing up to 10 residential water heaters (including HPWHs) under a program of cyclic operating conditions to generate durability data on an accelerated basis, which can support statistical estimates of service life. The facilities also support the *24-h Simulated Use Test*, and *First-Hour Rating Test* of the DOE Water Heater Test Procedure.

The **Vapor Compression Test Rig** is configured for evaluating the performance of one-off designs of vapor compression machines with both pure and mixed refrigerants. The rig has a variable-speed compressor, and the heat exchangers are refrigerant-to-fluid (water or brine).

The **Compressor Calorimeters** are used to verify performance of compressor designs. One calorimeter is designed for testing small fractional-ton compressors, such as those used in refrigerators and other small appliances and equipment. The second calorimeter is capable of testing compressors over the 1.5 to 4.0-ton range.

The **Air Coil Testing Loop** is designed for testing and evaluating the performance of refrigerant-to-air coils that are commonly used in most unitary HVAC equipment. Evaporator coils with a 2-ton capacity over the range of 40-50F and condenser coils up to 3-tons at 120F can be tested. The loop can move 7000 cfm of air against a 4-in (w.g.) coil pressure drop. The loop is configured for evaluating flow mal-distribution through the use of thermal imaging.

Building 5800/D-103 Equipment and Heat Exchanger Research Facilities

The **Large HVAC/R Environmental Chambers** have natural gas and electric utilities to support testing of large (up to 20 tons nominal capacity) commercial gas and electric heat pumps, rooftop units, desiccant systems, gas/electric packaged units, water heaters, refrigeration systems, and distributed generation/CHP systems (2 large rooms: 20’ x 20’ x 14’). There are two enthalpy tunnels inside the chambers. The chambers can hold a temperature range of -10F to 120F.

The **High Temperature Heat Exchanger Test Loop** features variable air flow from 10 to 1500 CFM, air temperature range up to 1100F, water supply temperature from 50F to 200F.

The **Low Temperature Heat Exchanger Test Loop** features variable air flow from 10 to 1000 CFM, air temperature range from -20F to 200F, and a compressor-less refrigerant system allows any refrigerant to be tested while avoiding lubricating oil performance impacts.

The lab also has **Computational Fluid Dynamics Modeling** tools including a large 65 inch LCD screen, computers with Quad processors, and FLUENT and COMSOL modeling packages.

Research Houses

Since 2002 ORNL has had an active program focused on residential systems- and building-level integration research. Through a partnership/alliance strategy, research houses are built and held

unoccupied for an extended research period through exclusive use leases. Each house focuses on one envelope strategy and the envelope retrofits that could be done on that strategy. The research period is long enough that several generations of equipment, appliances and controls can be investigated. Five Habitat for Humanity research houses have completed their research cycle and are now owned and occupied. Currently there are seven mainstream market research houses near the ORNL main campus (five comnpleted, one nearly so, one mid-construction). Four of the houses comprise the first Zero Energy Building Research Alliance (ZEBRAlliance) project, sponsored primarily by private-sector developer/builder, Schaad Companies. Three of the houses were sponsored by the Tennessee Valley Authority (TVA). All houses are available for R&D via exclusive use leases. The R&D program addresses different deep-savings envelope strategies and several generations of equipment, appliances, and controls enabled by the long-term leases. Schaad and TVA will eventually sell these houses.