Electrochromic Window Energy Testbed

Design Team
Kyle Borseti, Glen Fantuzzi, Mike Jastrzebski,
Bryan Katzenback, Jon Merlo

Design Advisor
Professor Yiannis Levendis

Abstract
Electrochromic (EC) windows are being used to reduce energy consumption and increase occupant comfort in buildings. EC window technology allows the user to control the tint level of the window by varying the applied voltage. The level of tint in the window is directly associated with the amount of solar radiation and light transmission passing through, enabling the user to control the solar heat gain and natural light levels. Current EC window technology lacks a control system that integrates the variable tint levels with a building’s HVAC system and interior lighting. This project will develop a scaled testbed prototype to evaluate efficiency and comfort based window programming. The testbed will simulate variable outdoor environmental conditions to collect data for a partner Industrial Engineering (IE) team developing control software.

For more information, please contact Y.Levendis@neu.edu.
The Need for Project

Electrochromic window technology currently lacks a control system that integrates the variable tint capability with building HVAC and lighting systems. With current building technology, creating comfort in most climates is achievable but costly and requires large amounts of energy. Recently there has been an increased interest in developing ways of reducing energy consumption from building systems. Electrochromic (EC) windows are a technology being used to reduce energy use and increase occupancy comfort in buildings. They use a small voltage to change the light transmission properties of the glass. This adjustment of tint level can vary the amount of light and heat passing through the window into the building. Currently the control of these windows is limited and has not been developed to maximize the window’s efficiency with building HVAC and interior lighting systems.

The Design Project Objectives and Requirements

To design and build a scale model of a typical office room and an outdoor environmental chamber for testing the performance of EC windows.

Design Objectives

The objective of this project is to design and build both a scale model of a typical outdoor facing room in an office building and a simulated outdoor environment for testing the performance of EC windows. Furthermore, to work alongside a group of Industrial Engineering students to develop an integrated control system for EC windows. The controller will monitor and use real time data to adjust window tint, interior temperature, and lighting levels to minimize energy consumption while maintaining occupancy comfort with regards to natural light levels and temperature. To successfully develop, test and optimize an EC window controller, the testbed (model room & outdoor chamber) required should accurately simulate a real life application. This project focuses on the design and construction of the testbed as well as initial testing of EC windows against a standard Low-E window. Both types of windows are of the same size and physical configuration (double-pane, 90% argon filled). The EC window was donated from the manufacturer SAGE Electrochromics and features four transmission set points; 62%, 20%, 6.0% and 3.5% (shown in the figures to the left).
**Design Requirements**

The testbed must include a scaled down model of an average office room as well as an exterior environment chamber. The model office is meant to replicate an average office with one full window wall typically found in a high rise building. The test window must be interchangeable to facilitate comparisons between the EC and standard Low-E window. The exterior environment chamber should be able to simulate outdoor summer and winter conditions including sunlight and temperature. The entire test apparatus should also be capable of measuring continuous temperatures at various locations.

**Design Concepts Considered**

**Model Room Concepts**

Determining the scale of the model room was among the first aspects to be considered. Options explored included a full size office room and a quarter-scale model. The full size model would offer challenges in terms of lab space, budget control, and outdoor simulation, but may arguably produce the most accurate results for our application. The quarter-scale model would be beneficial when dealing with lab space constraints, but challenges would arise when having to also scale down the corresponding building systems including HVAC and interior lighting needed for our design.

**Sunlight Simulation**

Two alternate lighting designs were considered when investigating how to appropriately simulate sunlight in the exterior chamber, the long arc xenon and the metal halide lamp. Though both options can provide accurate simulation, they require additional features such as voltage/current stabilizing ballasts and proper wavelength filters. For proof of concept and
a more economic approach, the current sunlight array in the testbed consists of 16 compact fluorescent bulbs and 2 infrared bulbs shown on the left.

Recommended Design Concept

Design Description

The testbed consists of two main compartments. The first compartment is a quarter scale model of an office room that has a full window wall exposed to sunlight. Appropriate building materials were used to mimic typical office construction. Each wall, ceiling, and floor was covered with R-13 insulation to minimize unwanted heat transfer into and out of the room. The amount of interior light necessary to meet OSHA standards was calculated and used to select the correct interior light fixture. The second chamber was designed to simulate exterior environmental conditions with regards to sunlight and temperature. It includes an 18 lamp light array to simulate the sun that consists of compact fluorescent and infrared lamps. The number and specified power for each lamp was calculated using typical solar irradiance levels and the size of the window wall. Additionally, metalized Mylar was applied to the inner walls of the chamber to increase the reflectivity and maximize the amount of light radiation that strikes the window. To achieve summer and winter temperatures in the exterior environmental chamber, a refrigeration system consisting of an evaporator, condenser and compressor was installed. This system, when combined with the infrared lamps of the light array, can maintain temperatures from 40°F (winter) to 90°F
(summer). Similar to the model room, the exterior chamber was fully coated with R-13 insulation to prevent unwanted heat transfer. To maintain an airtight seal, the two chambers latch together compressing a rubber gasket. Furthermore, casters on each compartment allow for ease of transportation.

**Experimental Investigation**

The testbed was used to test the EC window’s performance at all four tint levels (62%, 20%, 6.0%, 3.5% transmission) for both summer and winter conditions. The Low-E window was also tested at both exterior conditions for comparison. Testing included measuring temperatures at five locations continuously for 3 hours. Locations included inside the model room and exterior chamber, on the outer and inner window panes, and outside the testbed. The figures to the left specify the model room’s temperature change over the 3 hour test for all windows. During summer conditions (90°F), the Low-E window allows for the most heat gain and temperature change in the model room (14°F), while the EC window at 3.5% transmission reduced the solar heat gain and allowed for the least temperature change (4°F). A similar trend was found during the winter testing. Further tests were performed to evaluate the windows without sunlight exposure, simulating nighttime conditions at specified temperatures. These tests were used to find the temperature change in the room caused by the exterior temperatures alone, regardless of solar heat gain.

**Key Advantages of Recommended Concept**

The final testbed design was chosen with future testing and modification in mind. The model room allows for testing of any type of window as long as the framing fits in the window wall track. Materials chosen also allow for easy alterations for future testing, component additions, and other improvements.
The exterior environment is capable of maintaining temperatures from 40 to 90°F and effectively provides variable sunlight levels. The size of the entire testbed and attached casters provide an ease of mobility.

Financial Issues

The testing apparatus has cost roughly $2,500 to develop to date, with the majority of the costs attributed to the EC window and construction materials. A large amount of the construction in this phase is complete. Future costs will go towards installing an indoor HVAC system and testing and developing the window controller. Some aspects of the testbed were designed economically to provide proof of concept; therefore future costs could also consist of revisions to current components such as the light array.

Recommended Improvements

Another phase of the project is required in order to continue the background testing and use the data to further develop an EC window control system. An interior HVAC system should be added to collect data on energy usage while maintaining the room at specific temperatures and light levels. Moreover, a permanent interior light sensor should be installed inside the model room to collect and output accurate light levels during testing. These improved tests will provide useful information regarding the benefits of having a window that can vary the amount of solar heat gain when subjected to different exterior conditions (winter/summer). Using this data, a real time control system can be developed for the window to minimize energy consumption while maintaining occupancy comfort in a commercial or resident setting.