Chapter 4
Application of the Test Protocol

4.1 Experimental Setup

Two full-scale models were built and installed at the RDF (Research and Demonstration Facility), located in Blacksburg, VA. The models were construction between March and July, 2000. Figure 4.6 and 4.7 show the experimental setup.

4.1.1 Test Cells

The two window models were placed in two test cells. Each cell faces due south and is constructed of concrete blocks. The south side has an open grass field with no obstructions (Figure 4.1). The north wall of the test cell is a 36in x 36in opening to a long corridor with plastic skylight. Each test cell measures 8ft x 8ft x 8ft. During the test period, both test cells were well sealed (Figure 4.2, 4.3).

Figure 4.1 Outside the test cells

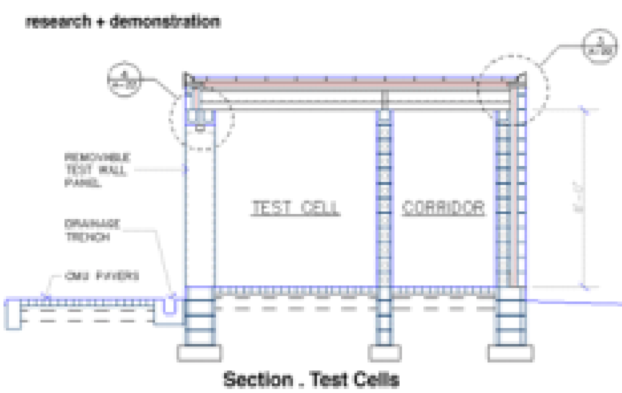


Figure 4.2 The section drawing of the test cell (CAUS, Virginia Tech)

Figure 4.3 The test cells

4.1.2 Windows

The full-scale window models were constructed of wood, metal, and glass and installed in the test cells. Each window measured 6ft width by 8ft height. One of the models represents the “Active System”, which uses a fan to produce airflow to vent the cavity. The other model represents the “passive system”, which allows unconditioned outdoor air to vent the window cavity. The detail drawings of the windows are shown in Appendix A and B.

4.1.2.1 Active System

The active system consists of two layers of glass, double pane outer and single pane inner, divided by an 8 inch wide air cavity. The composition of this window is as follows.

Outer layer glass- 48” x 72” double pane glass
¼” clear annealed
½” aluminum spacer
¼” clear annealed
Steady state U-value (approx): 0.48 Btu/(hr*°F*ft^2)

Inner layer glass- 48” x 72” single pane glass
¼” clear annealed
Steady state U-value (approx): 1.08 Btu/(hr*°F*ft^2)

48” x 72” white aluminum Venetian Blind

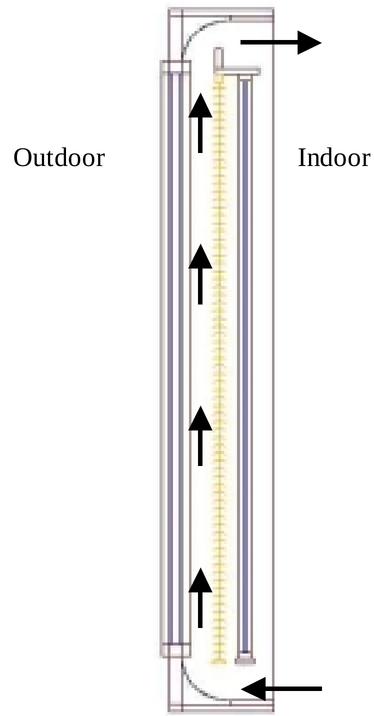


Figure 4.4 Active system section

4.1.2.2 Passive System

The passive system is similar to the active window except the air inlet and outlet are outside. Also the placement of the glass layers differs with the double pane layer inside and single pane outside. All the materials are the same for these two windows.

Outer layer glass- 48” x 72” single pane glass
¼” clear annealed
Steady state U-value (approx): 1.08 Btu/(hr*°F*ft^2)

Inner layer glass- 48” x 72” double pane glass
¼” clear annealed
½” aluminum spacer
¼” clear annealed
Steady state U-value (approx): 0.48 Btu/(hr*°F*ft^2)

48” x 72” white aluminum Venetian Blind

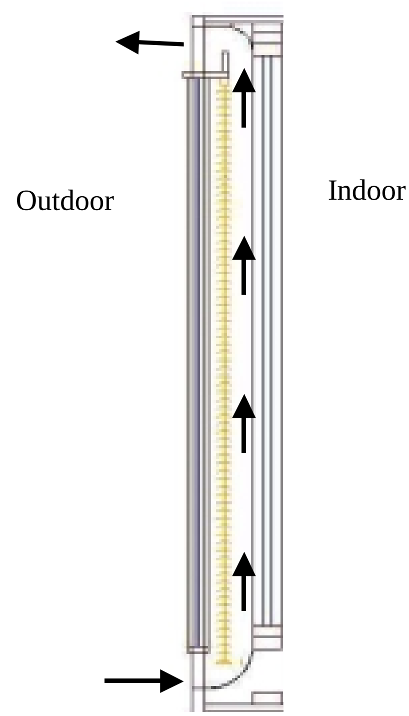


Figure 4.5 Passive system section

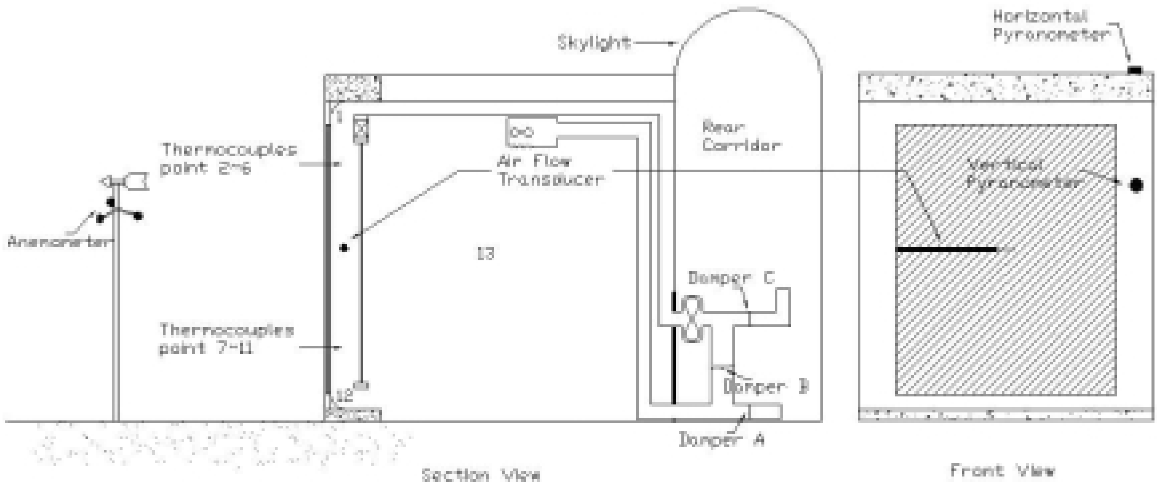


Figure 4.6 Active system layouts

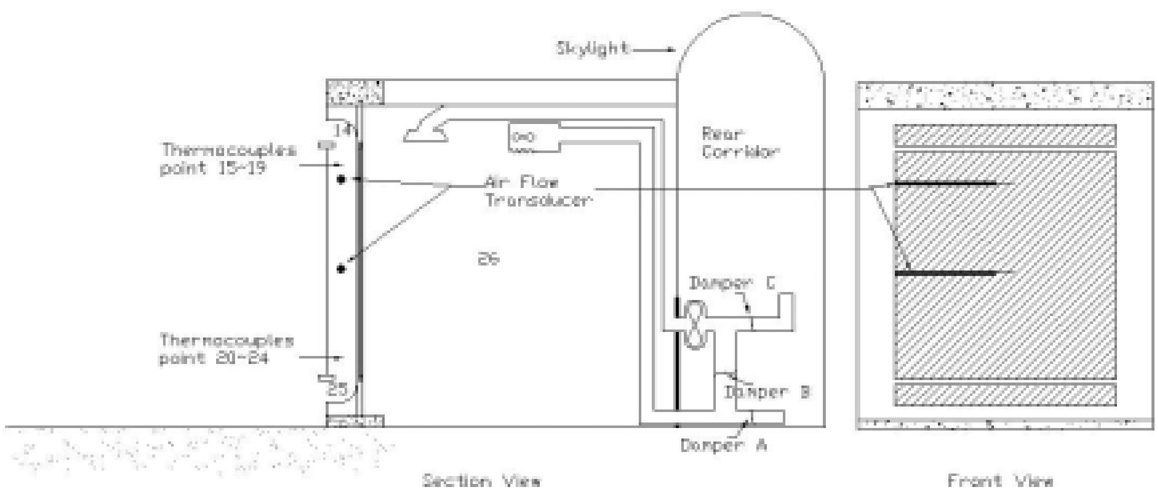


Figure 4.7 Passive system layouts

4.1.3 HVAC Systems

Both test cells were partially conditioned with a small heating and ventilation system. Both of the systems contain a ceiling heater and fan and a thermostat in each of the test cells. The ceiling heater and fan is a Broan Model 658, a fan forced heater, which can produce 4436 Btu/hr and 70 cubic feet per minute (cfm) of air flow. The fan and the heater work synchronously. The thermostat is a Honeywell Model CT62b, with a temperature setting range from 50°F to 80°F (10°C to 25°C) and the temperature differential is 2°F. The ceiling heater and fan hangs in the center of the cell about 7 ft high above the floor. Aluminum pipes and fans are used to introduce or expel the outside or inside airflow.

The ventilation flow rate was determined as described in Chapter 3. The setup of the HVAC systems are shown in Figure 4.8 and 4.9.

Figure 4.8 Ceiling Fan and Heater and Thermostat

Figure 4.9 The ventilation fans at the rear corridor

4.1.4 Recording Instruments

The instruments for recording data include thermocouples, anemometer, pyranometers, air flow transducers, data logger, and data storage module. Variables were measured as described in Chapter 3.

- Temperature
  Type T-copper constantan thermocouples were used to measure the temperature in the windows, test cells, and outdoor areas. This instrument had the following specifications.
  Maximum temperature: 221°F
  Accuracy: ± 1.1°F at 198.8°F

Window-
The thermocouples were attached to the glass surface or suspended in the window cavity. Each window section was divided into 12 different thermal zones and each zone had one thermocouple.

Test cell-
One thermocouple was set in the center of each test cell to record the room air temperature.

Outdoor air-
One thermocouple was located outside of the test cells about 5 ft away to record the outside air temperature.

Figure 4.10 Thermocouples are attached to or suspended from the glass surface

The thermocouple locations are shown in Figure 4.11, 4.12 and given in Table 4.1.

Table 4.1 Placement of thermocouples

	Active system		**Passive system**
1	Upper cavity airflow outlet temp	14	Upper cavity airflow outlet temp
2	Upper cavity outside glass pane temp	15	Upper cavity outside glass pane temp
3	Upper cavity outer air temp	16	Upper cavity outer air temp
4	Upper cavity inner air temp	17	Upper cavity inner air temp
5	Upper cavity inside glass pane temp	18	Upper cavity inside glass pane temp
6	Upper indoor air temp	19	Upper indoor air temp
7	Lower cavity outside glass pane temp	20	Lower cavity outside glass pane temp
8	Lower cavity outer air temp	21	Lower cavity outer air temp
9	Lower cavity inner air temp	22	Lower cavity inner air temp
10	Lower cavity inner glass pane temp	23	Lower cavity inner glass pane temp
11	Lower indoor air temp	24	Lower indoor air temp
12	Lower cavity airflow inlet temp	25	Lower cavity airflow inlet temp
13	Test cell room temperature	26	Test cell room temperature
27	Outdoor air temperature		

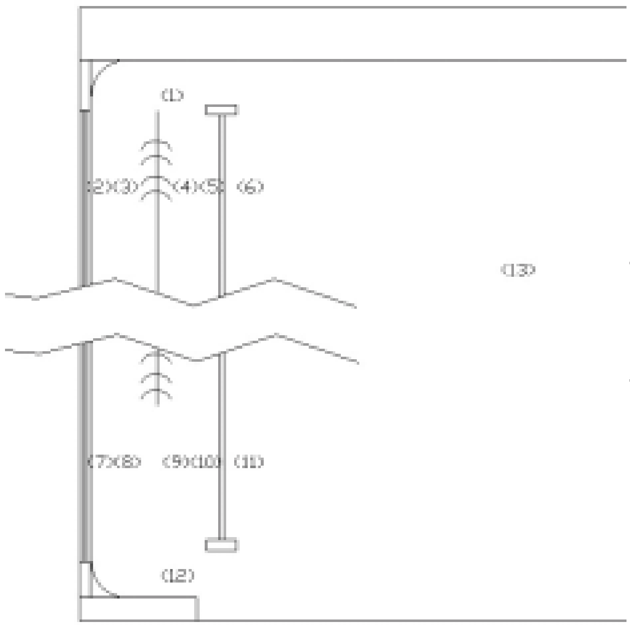


Figure 4.11 Thermocouple placement in the active system

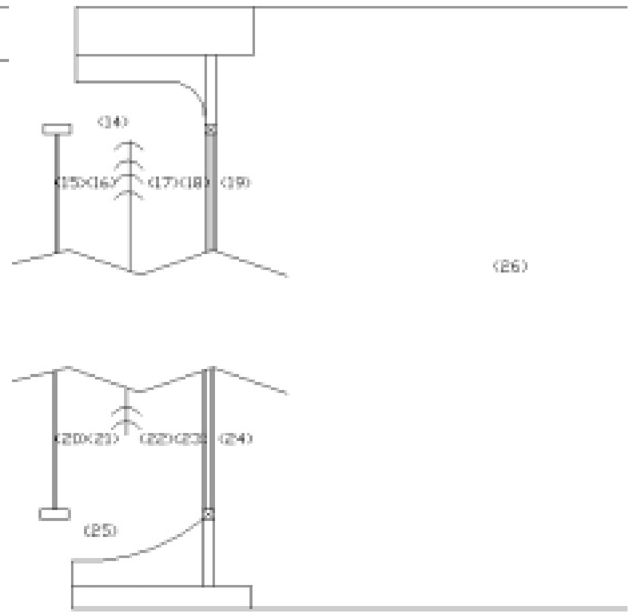


Figure 4.12 Thermocouple placement in the passive system

- Wind speed and wind direction
  A Met One 034 A-L wind monitor was placed outside the window models approximately 5 ft away from the wall and 5 ft in height. This sensor measured wind speed and wind direction near the experimental setup (Figure 4.13). This instrument had the following specifications.

  Wind speed-
  Operation range: 0 – 110 mph
  Threshold: 0.9 mph
  Accuracy: ± 0.25 mph for wind speed < 22.7 mph
  ± 1.1% for wind speed > 22.7 mph

  Wind direction-
  Range: 0 to 360°, shorting to ground between 356° to 360°
  Accuracy: ±4°
  Resolution: 0.5°

- Solar radiation
  Two Li-Cor LI200X Silicon Pyranometers were used to record solar radiation. One was attached to the window frame and faces south. This sensor measures the vertical solar radiation near the window. Another pyranometer was set on the top of the window to measure the horizontal solar radiation (Fig 4.14). This instrument had the following specifications.

Accuracy: Absolute error in natural daylight is ±5% max; ±3% typical
Sensitivity: 0.2 kW m^{-2} mV^{-1}
Light spectrum waveband: 400 to 1100 nm

- Air flow velocity
  Three TSI Model 8475 Air Velocity Transducers were installed in the window cavity to monitor the cavity airflow rate. Because of the likely fluctuation of the airflow rate in the passive system, two transducers were located at the upper and lower cavity in order to obtain an average airflow rate. Another transducer was located at the middle of the active window cavity. All the probes were located away from the air inlets and outlets to avoid turbulence (Figure 4.15 & Fig 4.16). This instrument had the following specifications.

  Range: 10 ft/min to 100, 125, 150, 200, 250, 300, 400, or 500 ft/min (selectable)
  Accuracy: ± 3.0% of reading from 68 to 78.8°F, outside this range add 0.28% per °F
  ± 1.0% of selected full scale range
  Response time to flow: 5 seconds
  Minimum resolution: 0.07% of selected full scale

- Data logger and storage module
  Three Campbell Scientific 21X data loggers and three SM192 storage modules were used to collect and store data. This equipment had the following specifications.

  Campbell Scientific 21X data loggers-
  Common mode range: ± 5 volts
  Accuracy: Differential and positive single-ended: 0.1% FSR (0.05%, 32-96°F)
  Negative single-ended: 0.15% FSR (0.06%, 32-96°F)

  SM192 storage modules-
  Operating temperature range: -31°F to + 149°F

4.2 Experimental Operation

During the test period, to prevent unacceptably cold indoor temperatures, the thermostats for both test cells were set at 65°F. Both fans were on throughout the data collection period to simulate an occupied condition in a non-residential building.

4.2.1 Data Collection

Data were collected during the test period from September through October 2000. Monitored variables included: temperature (27 points), wind speed and wind direction, solar radiation (vertical and horizontal), and inside cavity air flow rate. Data measurements were taken every 10 seconds. Every fifteen minutes both instantaneous and average values of the 10 seconds records for each sensor were

Figure 4.13 Anemometer for wind speed and direction measurement

Figure 4.14 Vertical and horizontal pyranometer

Figure 4.15 Installation of the air flow transducer

Figure 4.16 Installation of air flow transducer in ventilation cavity

calculated and stored in a Campbell Scientific 21X data logger. Data were then transferred to a SM192 storage module. Recordings were made every 15 minutes.

4.2.2 Active System Operation

Figure 4.17 Air outlet slot connects to ducts

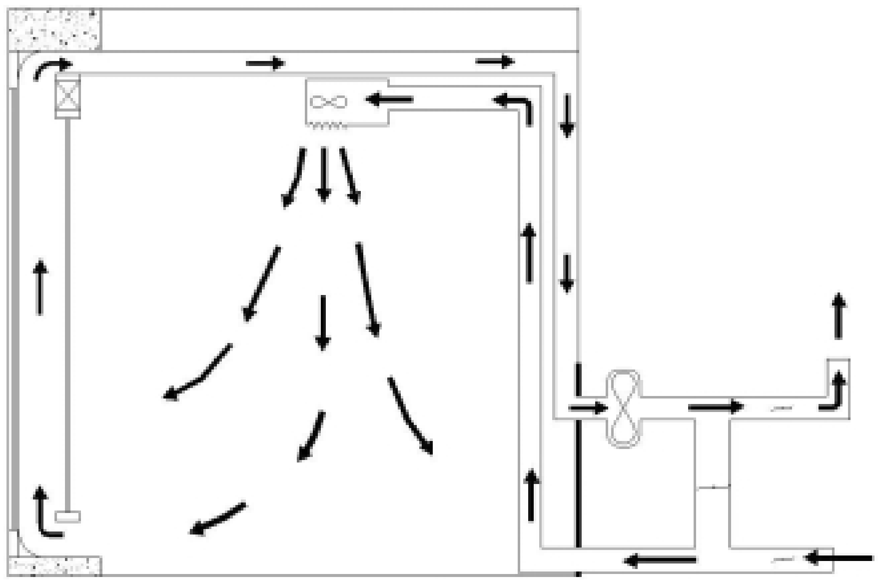
The active window system integrates with the HVAC system to let the electrical fan vent the cavity air. The air duct connects to the window cavity air outlet (Figure 4.17). When the fan is on, air is drawn through the cavity. The indoor air is pulled into the cavity via the bottom inlet. The cavity air was expelled to outside. This mode is representative of summertime operation. When the value of solar radiation is high, the window cavity gains more heat and temperature is likely to rise. This hot air is unwanted in summer period, so a damper (damper A) is opened in order to dump the cavity air to outside. Damper B will close to separate the outgoing airflow and incoming airflow. Damper C will open to introduce the outdoor fresh air.

4.2.3 Passive System Operation

Fig 4.18 Returning air intake

The HVAC set up for passive system is similar to the active system, except the supply and return air distribution is more conventional (Figure 4.18). The outdoor air enters the indoors through the ducts and then the fan draws out the indoor air and exhausts it to the outside. The passive system also has the same operating mode as the active system. The damper A and damper C remain opened while damper B keeps closed.
The experimental operation and air flow pattern are shown in Figure 4.19. Throughout the data collection period, all the instruments and operations remained the same.

	Active System
Damper A	Opened
Damper B	Closed
Damper C	Opened



	Passive System
Damper A	Opened
Damper B	Closed
Damper C	Opened

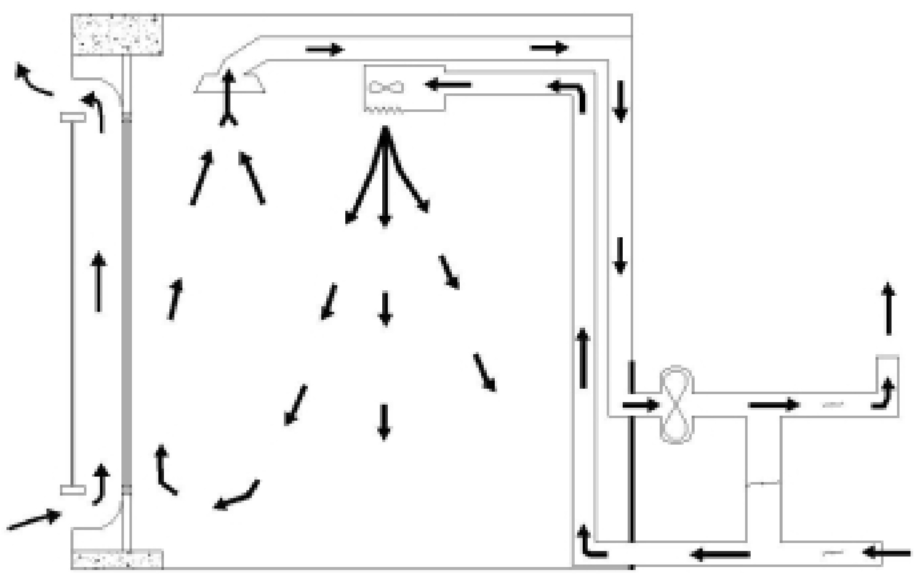


Figure 4.19 The experimental operation modes