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A Research Note on:

*DEVELOPMENTAL SPECIFICATIONS FOR A CONTROLLED
ENVIRONMENT TEST UNIT*

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ABSTRACT

The purpose of this paper is to present the specifications and standardization process for the development of a controlled environment test unit. Research on the topic of energy radiation, conduction and convection has focused on the testing of materials and composite wall construction to prevent energy transfer in buildings. However, after energy has entered a building, investigation of the dispersion of the transferred energy has been neglected. This research note presents a method of building and standardizing such a facility enabling researchers to explore air dispersion when introducing energy into a human-scale closed room.

PURPOSE

The purpose of this paper is to document the design and construction of the Controlled Environment Test Unit (CETU) used in the testing of energy phenomena of interior spaces by Sherman (1983).

LITERATURE REVIEW

Passive solar-energy research is, in most experiments, conducted in various sized chambers or "hot boxes." Few, however, are conducted in rooms specifically designed for energy-data acquisition from trapped air volumes. A large majority of the energy research regarding windows, drapery, roller shades or other window coverings and various building wall constructions have neglected to study the effect of temperature dispersion in controlled room conditions. Data reported by these studies, if applied to real room situations, are generalizations extrapolated to fit real scenarios. The effects of energy transmission on trapped air volumes as a result of convective air currents are examined in this research note. Studying the rate of resistance ("R" value) of a particular building product is important for information about insulation effectiveness. When the energy is eventually transmitted to the interior volume of a room, dispersion patterns of the energy by air convection should be examined to fully develop an energy management program.

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Sherman (1981) quantifies wall characteristics from surface temperature and heat fluxes. His data are pertinent to heat flux of wall construction but do not investigate the effects of the conductive or radiant heat on a room-size volume of air. The convective currents generated by conductive and radiant heat transfer are not tested or measured.

Feather (1980) studies fabric weight and fiber content of drapery in a controlled thermal unit. The insulated thermal cabinet contained a simulated window and a thermostatically-controlled heat source. Although Feather's data may be accurate, the results must be interpolated for actual use in an interior setting. Full-scale research would allow analysis of the cause-effect relationship between the drapery and the interior environment.

McLain and Rogers (1981) discuss window design and its effects on energy consumption. They use floor plans and elevations to depict both the energy and aesthetic qualities of windows.

A portion of their results show that an interior designer should be knowledgeable regarding insulating window treatments or movable insulation.

Evaluation of thermal resistance of the exterior of a building using thermal sensor mountings was conducted by Wright et al. (1981). Their research investigates the effect of surface-mounted sensors and bonding agents used to affix the sensor to the wall. While their experiment examines surface phenomena, it does not examine the effects of the temperature loading on the interior chamber.

Grasso (1977) measures thermal transmission through roller shade systems using an 8-by-8 framed wall with temperature probes on either side of the window coverings. Grasso explores the effectiveness of the window covering with regard to fabric, edge treatment, and distance. However, energy transmission is not studied in the context of a full-scale room. Therefore, the cause-and-effect relationship between the window covering and a room is only a conjecture.

Dix and Lavan (1974) indicate that window coverings have a great deal to do with window energy conservation. Again, the research is not done in an environmentally-controlled room. Hence, the convective currents produced by the windows are not examined.

Sherman (1983) tests a full-scale Controlled Environment Test Unit (CETU) monitoring the effects of drapery on heat transmission through windows. He concludes that interior environments are directly affected by the transmission of heat in three forms: radiation, conduction and convection. Conduction and convection directly affect air current movement. The effects of the air dispersion currents in the full-scale test unit were recorded by temperature probes. He concludes that monitored air currents directly affect the ability of drapery to reduce the heat transmission and, had the research been performed in a small-scale, simulated condition test chamber, the results would have been very different.

Orlandi (1981) uses a Hewlett-Packard 9835-A computer for data acquisition, reduction and mass storage requirements. This technique is similar to the data acquisition system developed for use in the research presented in this paper.

Allmon (1981) identifies five heat-loss sources in insulated systems. One is free convective flows. He states that it is common to base heat-loss calculations on the insulated surface only. The research reported in Allmon's paper supports the hypothesis that the CETU is a useful testing procedure for evaluating the convective air flow in a full-size room. Dispersion of a thermal load by convective air flow can be monitored with the use of temperature probes and a computer-based data acquisition system.

To examine the effects of convective air currents caused by radiation and conduction of heat energy on a room, no internal barriers such as furniture or fixtures are installed. This corroborates the research found in the Annual Book of ASTM Standards (ASTM, 1983). Those standards indicate that it is not necessary and may be improper to install barriers to internal convection when a closed test chamber is used in an experiment of this type.

Specific data collected for energy conservation when simulated in reduced-scale apparatus should not be presented as if they were directly applicable to full-scale situations. The performance of particular window coverings should be accurately assessed in full-scale test facilities where the complete range of interior phenomena can be studied in a cause-and-effect relationship.

METHODS

To collect data on and study a natural phenomenon, that phenomenon must be separated from others that are similar in cause, but different in effect. This CETU was constructed inside a university laboratory setting with its own standard thermostat and exterior windows facing the north and the west.

Dimensions of the room were chosen to be 10 feet wide, 20 feet long and 8 feet high. These measurements were used to simulate a human-scale room that could have the entire longitudinal wall photographed from the opposite parallel wall to document air dispersion within the CETU. Another critical design parameter was that a human-sized room was necessary for future use of human subjects in the unit. Finally, the review of literature showed that most energy research with window or window coverings took place in very small box-like test chambers or desk-top watt meter small-scaled window configurations.

Construction of the CETU used standard 2-by-4 wooden studs common in residential buildings. The only modification to this particular construction was that a vapor barrier was applied to the exterior of the structure for the purpose of keeping external air pressures from modifying the internal air convection and temperature dispersion. This vapor barrier was attached to all six sides of the CETU.

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Floor construction for the CETU was composed of 2-by-6 Southern White pine wood joists, placed vertically every 16 inches on center spanning the width of the room. These floor joists were placed directly on the vapor barrier with several feet of the vapor barrier extending in all four directions to overlap with the wall vapor barriers. An exterior ribbon of 2-by-6 joists was placed on the two 20-foot edges of the joists to add stability to the floor. In the spaces between the floor joists, six-inch-wide, kraft-backed fiberglass insulation was placed kraft-side toward the vapor barrier. The sub-floor construction consisted of 3/4 inch tongue and groove, exterior-grade plywood. This whole structure was glued and nailed to the floor joists.

The two 20-foot walls were constructed of 2-by-4 Southern White pine studs and placed in standard configuration every 16 inches, with a single bottom sole plate and a double top plate. These walls were assembled in a horizontal position and were raised into place after they were constructed. Both walls were stabilized with temporary supports while the two 10-foot long walls were being constructed.

The next wall constructed was the 10-foot wall having the rough door opening for CETU access. It was built exactly like the other walls with the door opening framed in standard end-post and lintel construction. The second 10-foot wall had a rough opening for a window. Both 10-foot walls were lifted into place when finished. All four walls were tied together with the double top plate. The bottom sole plate was nailed to the sub-floor and the temporary supports were removed.

The ceiling construction, the last step in the framing, was identical to the floor construction. Once it was completed and put in place, the entire framing job was finished. At this point in the CETU construction, with the rough wood framing in place, the entire structure was rigid and ready for interior finish application.

The next step in the CETU construction deviated from standard residential construction because at this point in the standard construction sequence exterior siding would be applied. Deviation from this step was essential. No rigid exterior could be applied to allow easy access to the walls for probe wire movement, camera placement and future placement of equipment or other structural modification. However, some form of rigid surface had to be applied to ease the installation of the kraft-backed fiber glass insulation. Therefore, the interior drywall was next in the construction sequence. Drywall (3/8") was nailed to the interior walls, followed by standard taping and pasting processes.

After the drywall installation, the electrical lines were installed. Because the electricity could not be shut off for hard wiring procedure, any wiring for either the probes or the 110-volt lines had to be wired to a junction and then routed for final placement. Therefore, each junction box had a long extension cord attached to ganglia of wires. The wires were then routed to the junction box allowing the researcher to then plug in the junction box without further electrical complications.

The only 110-volt lines that were needed for future use were duplex receptacles, interior switch plates and ceiling junction boxes. All these were wired and secured in place. At this time, the ceiling junction boxes were not exposed. However, the blueprint for the CETU notes their exact location above the ceiling so they can be located and accessed when needed.

A heating and cooling system was also installed. The heating system consisted of a flush wall-mounted resistant heater with a variable speed blower. The BTU rating was chosen allowing some heat rise in the CETU to develop an uncomfortable temperature for humans, but was not rated high enough to develop any relatively dangerous temperatures.

The cooling unit was installed in three parts. Two standard air diffusers were equally spaced at the ceiling level on one of the 20-foot walls. Flexible tubing was attached to the rear of the diffusers and routed to a window air conditioner. A specially designed two-holed boot with flanges was constructed. It was attached to the cooling part of the air conditioner. The flexible hose was then clamped to the flanges of the boot, providing air cooling for a window mounted air conditioner to the CETU by way of flexible hoses and two wall-mounted air diffusers.

Next in the construction sequence for the CETU was the installation of the windows and doors. Since either or both of these items could be part of a particular experiment, the type installed is not important. The size of the actual window was 6-by-6 to allow for windows to be added or removed without reframing the main structure. The door size was 3 feet wide and 6 feet-8 inches high. This would allow size changes to be made without reframing the CETU. In this step, a centrally-located opening was created to pull the probe cables into the interior of the CETU.

Following complete closure of the CETU, the insulation was friction-fit into place between each wall stud and ceiling joist and stapled to the adjacent wood member. Once the insulation was completed, the vapor barrier was applied to all the surfaces. Each sheet was overlapped, taped at the joints, and where appropriate, attached and taped to the floor vapor barrier.

For the experiments requiring heat, adequate space was constructed at the window end of the CETU. The heat source in this test unit was an independent rack supporting 14 aluminum light fixtures with standard wattage light bulbs. This portion of the CETU construction would vary depending on the research requirements. The last step in the construction series was completed.

The next task was connecting the temperature probes to the computerbased Data Acquisition System (DAS). The probes were equally spaced within the CETU, leaving one probe on the exterior of the unit to monitor the laboratory conditions. Once this was completed, a series of standardization tests were run, providing a baseline of temperatures. The standardization tests were run in a 5-day (96 hour) series, where the interval between samples collected was 10 minutes. The duration of the energy tests and the sample

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interval was chosen because these were the experimental parameters of the first application of the CETU. The results of the standardization tests showed that there was no temperature fluctuation (0 degree centigrade) documented on any of the baseline data collected.

SUMMARY

The design and construction of the Controlled Environment Test Unit was a success because no temperature fluctuation occurred during the standardization testing. The CETU proved to be a reliable research tool for studying the dispersion of energy by convective air currents. Energy phenomenon at naturally occurring levels in human interior environments should be studied in a room with human scale, such as the CETU.

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