

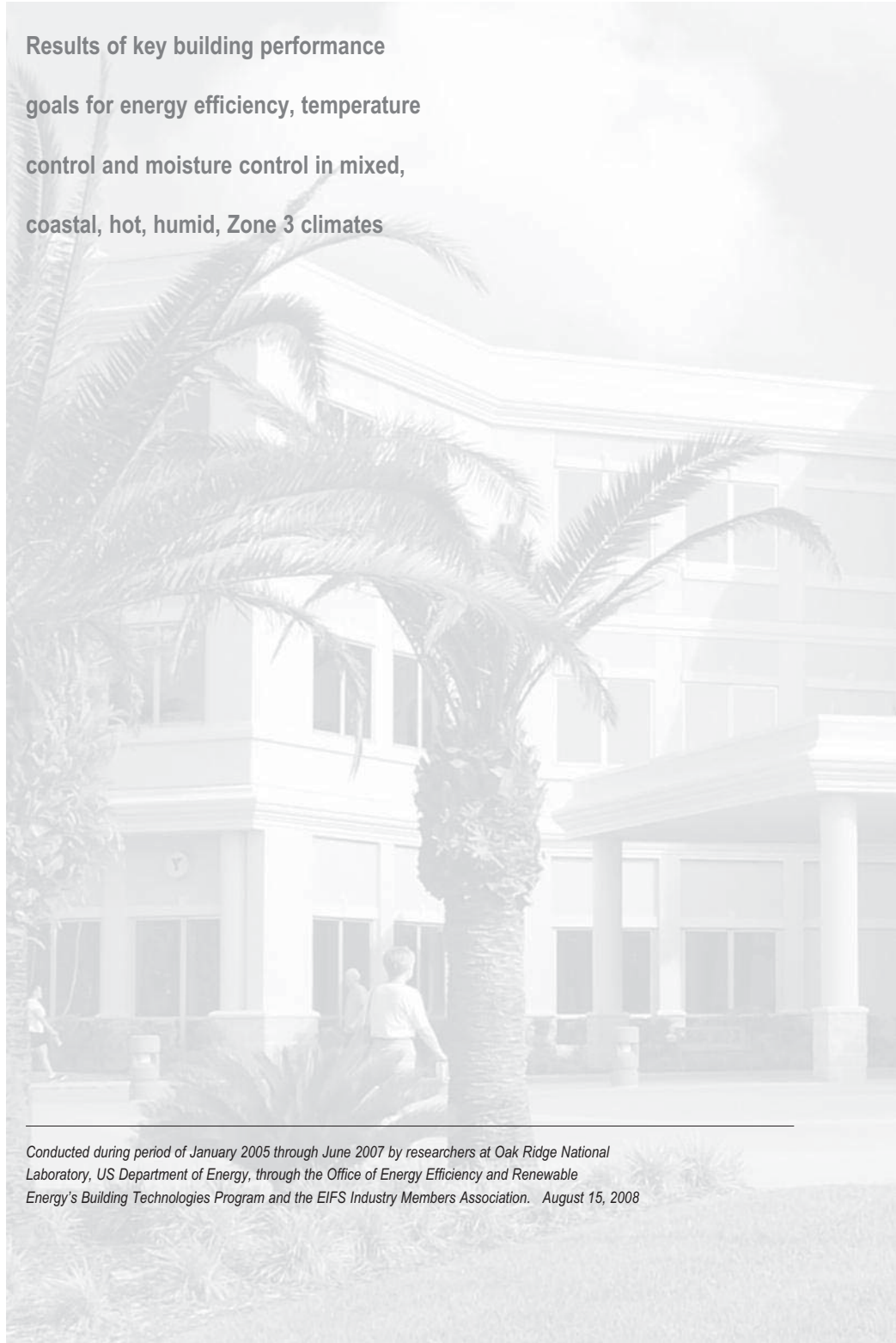


EXECUTIVE SUMMARY EXTERIOR WALL CLADDING PERFORMANCE STUDY

Results of key building performance
goals for energy efficiency, temperature
control and moisture control in mixed,
coastal, hot, humid, Zone 3 climates

EIFS INDUSTRY
MEMBERS
ASSOCIATION

Conducted during period of January 2005 through June 2007 by researchers at Oak Ridge National Laboratory, US Department of Energy, through the Office of Energy Efficiency and Renewable Energy's Building Technologies Program and the EIFS Industry Members Association. August 15, 2008



EIFS Performs: Excellent Choice in Mixed, Coastal, Hot, Humid Climate for Energy Efficiency, Temperature and Moisture Control

In this era of sustainable, green building, energy efficiency has once again become the most widely publicized and used benchmark by which successful building design and operation is measured. Control of thermal energy flow and moisture by the building envelope is key to energy conservation, preservation of the construction and its contents, and occupant satisfaction. The choice of exterior cladding and how well that cladding is installed is critical to achieving two principal goals that drive the design, construction, operation, and maintenance of U.S. homes and commercial buildings:

- Energy efficiency
- Moisture and temperature control

Up to now, what has been lacking is a full understanding of the hygrothermal (temperature and moisture control) performance of all types of wall systems for typical climactic effect, such as wind driven rain, rainwater penetration, condensation, solar and night sky radiation, wind speed, and site/wall orientation. This lack of understanding stems from insufficient real-world data and has resulted in misinterpretations of how wall systems as a whole perform.

The results of a new landmark study provide for the first time ample real-world data demonstrating that EIFS clad wall assemblies with drainage (EIFS) outperform other typical U.S. exterior claddings (Brick, Stucco and Cementitious Fiberboard Siding) during most of the year. The results also demonstrate that EIFS is an excellent exterior cladding choice for achieving key building performance goals in a hot and humid climate, specifically a mixed, coastal, Zone 3 climate¹.

The US Department of Energy (DOE), through the Office of Energy Efficiency and Renewable Energy's (EERE) Building Technologies Program, and the EIFS Industry Members Association (EIMA), sponsored the study, which was conducted by researchers at the Oak Ridge National Laboratory (ORNL). A building was constructed near Charleston in Hollywood, South Carolina, featuring panels with various wall claddings and assemblies. Each of the wall panels in which the claddings had been incorporated contained sensors that provided a full profile of temperature, heat flux, relative humidity, and moisture content. These sensors collected data 24 hours a day, 7 days a week, and transmitted the data to the ORNL research facility in Oak Ridge, Tennessee for analysis (see Measuring Wall Systems Performance below for more information about the building, wall panels, and sensors).

One of the strengths of this study is that it considered the building envelope in its entirety, along with studying isolated materials or components of the exterior claddings. The other strength is that the wall was exposed to real climactic loads. This study allowed the researchers to gather real-world data over a 30-month period (Phase I January 2005 - May

2006 and Phase II June 2006 - June 2007). Phase II continued Phase I conditions except a design "flaw" was created in specific specimens to introduce water into them. The following summarizes the key findings of this study, all of which are applicable to a mixed, coastal, Zone 3 climate:

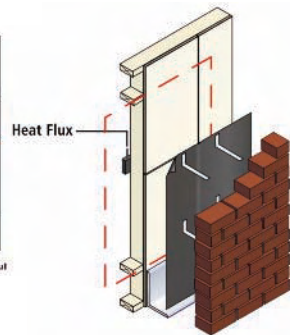
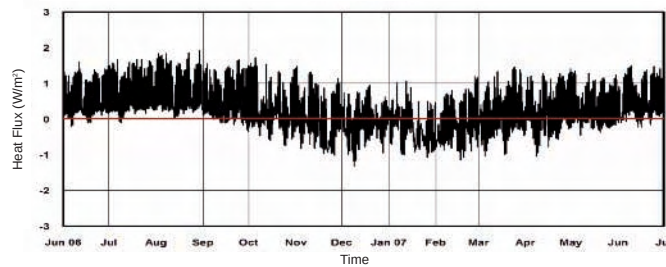
- In Phase II, one of the best performing wall system configurations was comprised of EIFS that included a liquid applied water-resistive barrier coating and four (4) inches of expanded polystyrene insulation board. In addition, all of the thermal insulation was placed outbound of the sheathing (no stud cavity insulation). This EIFS wall configuration performed better than brick. Brick had the lowest thermal and moisture performance among the claddings and wall configurations studied, followed by stucco (both 3-coat and 1-coat) (Fig. 1).
- EIFS walls maintained a consistent, acceptable level of moisture (average monthly relative humidity below 80 percent, as defined by ASHRAE SPC 160P, *Design Criteria for Moisture Control in Buildings*), within the cladding despite varying outdoor conditions when appropriate interior vapor retarders were used. Brick and stucco tended to accumulate slightly more moisture during both Phase I and Phase II of the project and retained moisture longer than EIFS (see Fig. 2 which represents the measured relative humidity on the face of the exterior sheathing).
- EIFS and a liquid applied water-resistive barrier coating readily dispersed moisture introduced by flaws (installed in Phase II) in the building envelope, as compared with brick, which retained more water (see Fig. 3 which represents the measured moisture content on the face of the exterior sheathing).
- Liquid applied water-resistive barrier coatings, in certain instances as described later on in this report, outperformed other water-resistive barriers in this study. In addition, EIFS with water-resistive barrier coatings performed significantly better than other EIFS claddings that used building paper or spun-bonded polyolefin membranes. The results also indicated that building wraps permit greater vapor transport inward in mixed climates (see Fig. 4 which provides recorded relative humidity on the inside face [stud cavity side] of the exterior sheathing).
- Insulation located on the exterior (outside of the stud cavity) is more effective since it maintains the sheathing and insulation at drier levels. This has important implications for preventing material degradation (see Fig. 5 which provides the measured relative humidity on the face of the exterior sheathing).
- The results of this study validate that vertical ribbons of adhesive provide an effective means of drainage within an EIFS clad wall assembly (see Fig. 9).

¹ 2006 International Energy Conservation Code

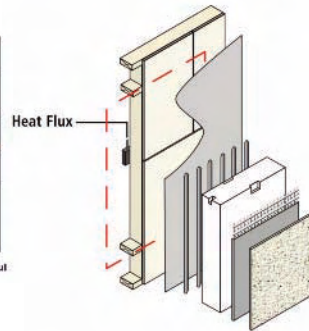
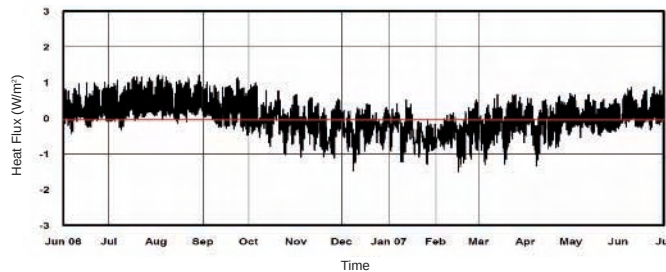
FIG 1

Comparison of Heat Flux Sensor on inside face of interior gypsum wall board in Brick, EIFS and Stucco assemblies

Brick Panel 15
Brick ties over
1 layer of grade D
60 minute
Heat Flux Sensor



EIFS Panel 5
4" EPS without
batts in stud cavity
Heat Flux Sensor



Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Heat Flux Sensor

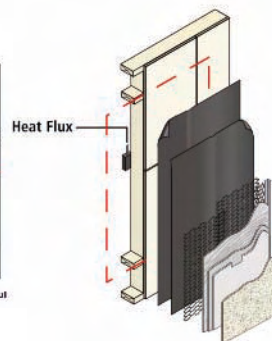
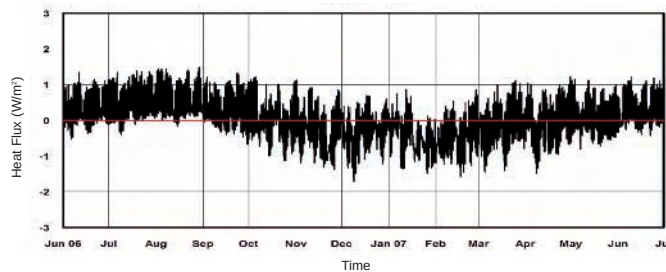
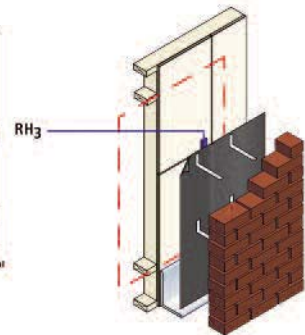
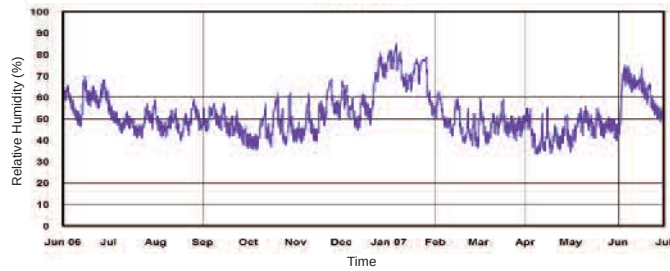


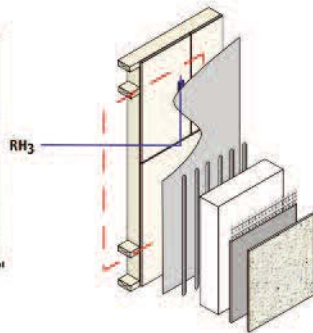
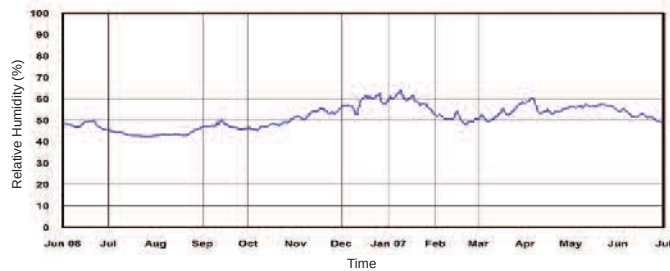
FIG 2

**Comparison of Relative Humidity Sensor 3 (RH3) behind
Water Resistant Barrier in Brick, EIFS and Stucco Assemblies**

Brick Panel 15
Brick ties over
1 layer of grade D
60 minute
Sensor RH 3



EIFS Panel 5
4" EPS without
batts in stud
cavity
Sensor RH 3



Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 3

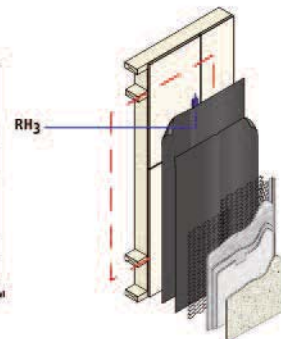
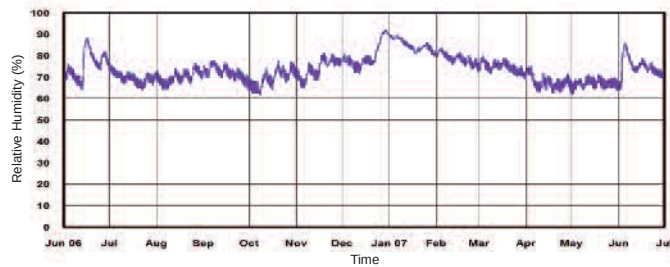


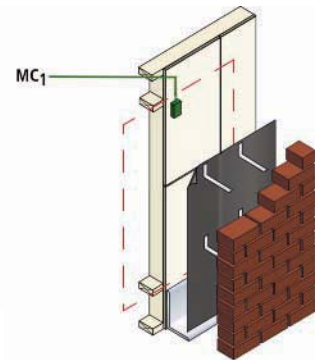
FIG 3

Comparison of Moisture Content Sensor 1 (MCR1) of wood sheathing behind Water-Resistive Barrier in Brick, EIFS and Stucco Assemblies

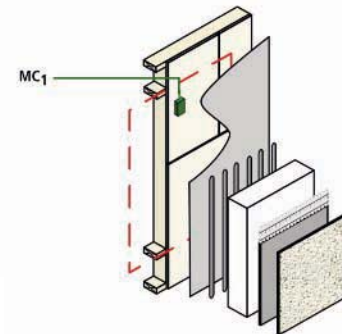


MC Sensor

Brick Panel 15
Brick ties over
1 layer of grade D
60 minute
Sensor MCR 1



EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor MCR 1



Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor MCR1

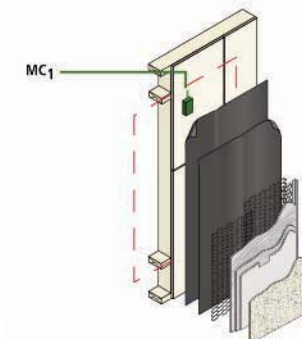
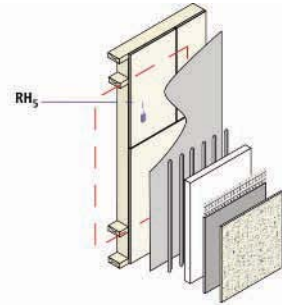
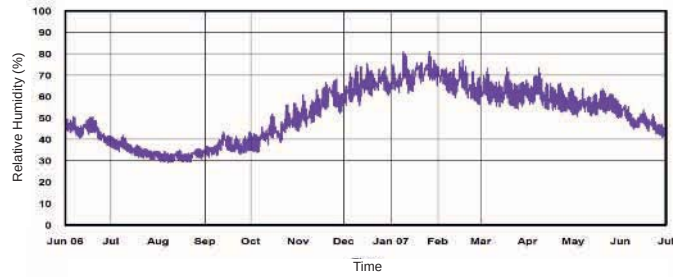


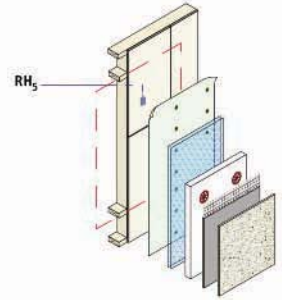
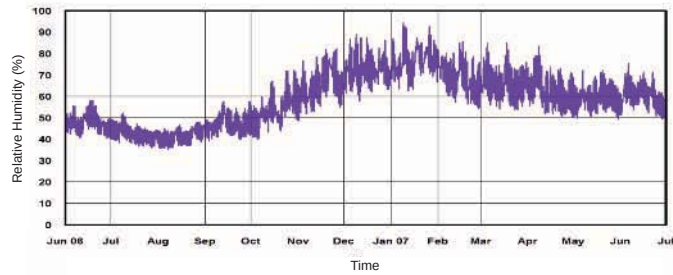
FIG 4

Comparison of Relative Humidity Sensor 5 (RH5) at inside face of sheathing in EIFS, Stucco and Brick Assemblies

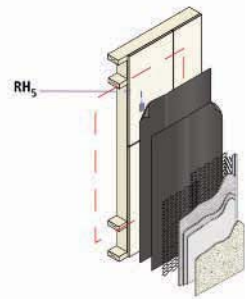
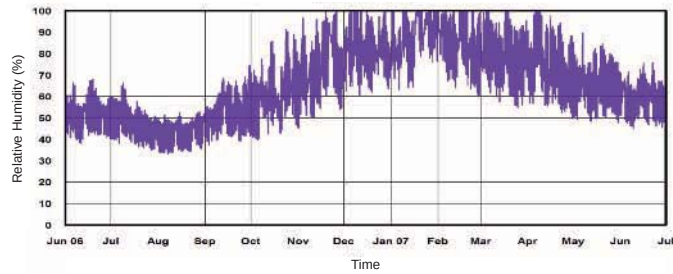
EIFS Panel 2
1.5" EPS plus
batts in stud cavity
Sensor RH 5



EIFS Panel 9
1.5" EPS plus
batts in stud cavity
Sensor RH 5



Stucco Panel 12
Metal lath over
2 layers grade D
60 minute
Sensor RH 5



Brick Panel 15
Brick ties over
1 layer of grade D
60 minute
Sensor RH 5

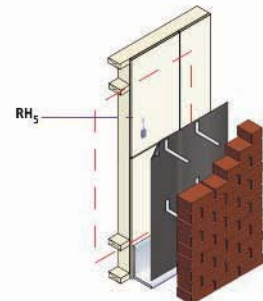
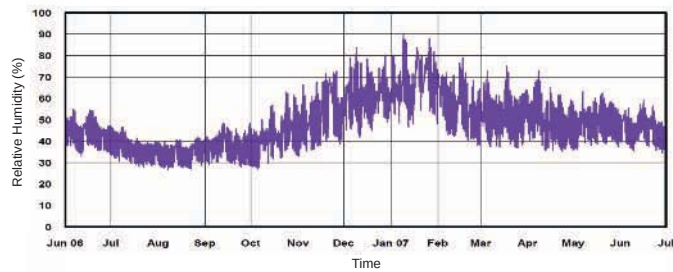
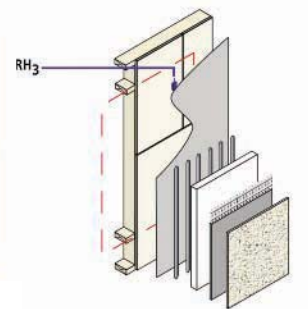
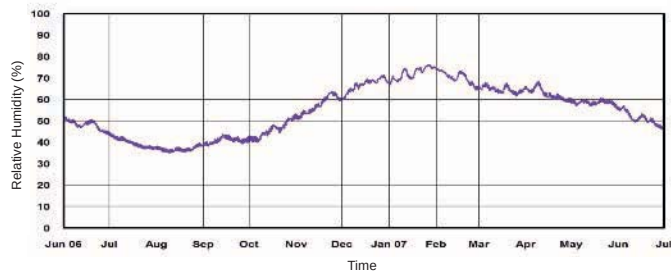


FIG 5

Comparison of Relative Humidity Sensor 3 (RH3) at
inside face of sheathing behind Water-Resistive Barrier
in 1.5" and 4" EIFS Assemblies

EIFS Panel 2
1.5" EPS plus
batts in stud cavity
Sensor RH 3



EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 3

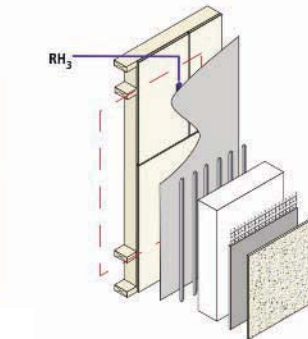
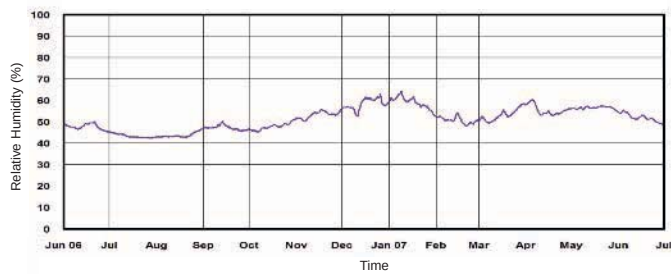
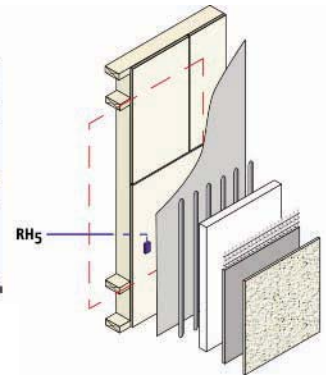
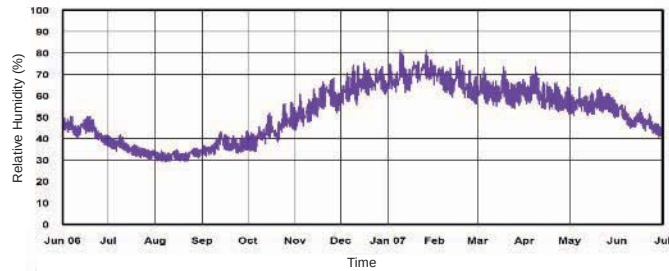


FIG 6

**Comparison of Relative Humidity Sensor 5 (RH5)
at inside face of sheathing in EIFS and Stucco Assemblies**

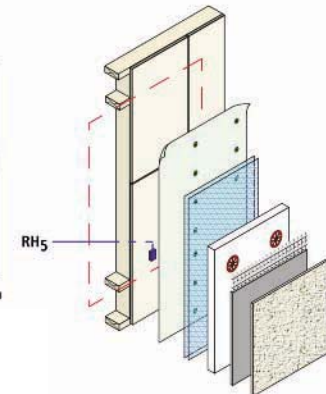
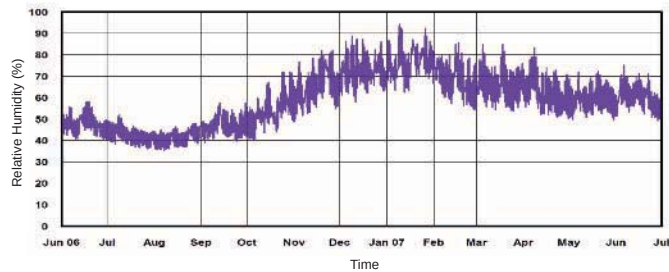
EIFS Panel 2

Vented - Vertical
adhesive ribbons
over liquid applied
WRB plus batts in
stud cavity
Sensor RH 5



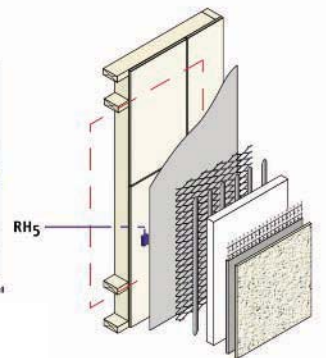
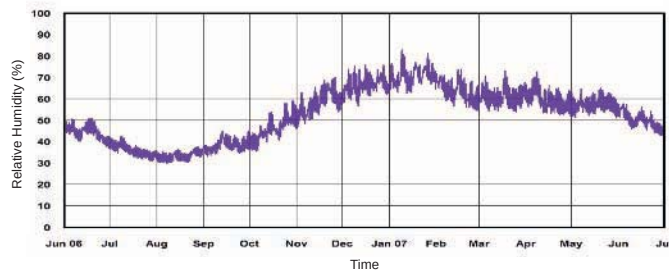
EIFS Panel 9

Vented - Drainage
mat over SBPO
WRB plus batts in
stud cavity
Sensor RH 5



EIFS Panel 10

Ventilated - Lath
over liquid applied
WRB plus batts in
stud cavity
Sensor RH 5



Measuring Wall System Performance

The researchers in consultation with the EIFS Industry Members Association (EIMA) designed and built a test facility in Hollywood, South Carolina near Charleston, a location that is typical of a mixed, coastal, Zone 3 climate, as prescribed in the 2006 International Energy Conservation Building Code. The building's flexible design allowed researchers to change the wall panels with ease and to control conditions inside the building by creating two zones within the building's interior (Figure 7). Interior temperature and relative humidity conditions were selected based on the proposed ASHRAE SPC 160P standard. Building orientation and placement of the wall panels were determined based on a comprehensive study of historical weather patterns, including prevailing wind and precipitation direction.

This research uses multiple assemblies of materials suitable for both field exposure testing and computer modeling. Tested assemblies include both

configurations with material properties typical of commercially available systems and configurations not currently available. A manufacturer or supplier should be contacted for commercially available assemblies.

The data were collected in two phases. Refer to Table 1 for wall configurations that were evaluated in Phase I, and to Table 2 (page 12) for wall configurations evaluated in Phase II of this study.

In Phase I, 15 exterior cladding configurations were integrated into one side of the building (southeastern exposure), with the goal of having all the claddings exposed to similar weather conditions for a full weather year (15 months from January 2005 through May 2006) (Figure 8). In addition, the hygrothermal performance of three innovative EIFS features (liquid applied water-resistive barrier coatings, smart vapor retarder systems, and exterior cladding ventilation) were evaluated. Table 1 lists the configurations of these 15 wall panels.

TABLE 1
Phase I Configuration of the
Exterior Wall Assemblies Investigated

Panel / System	EPS	Attachment	Drainage / Air Space	Weather Barrier	Sheathing	Framing	Cavity Insulation	Vapor Barrier
Panel 1 EIFS	1-1/2" Flat	Ribbon & Dab	NA	NA	None	CMU	None	Note 1
Panel 2 EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 3 EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	smart vapor retarder
Panel 4 EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	Yes
Panel 5 EIFS	4" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	None	None
Panel 6 EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	18 ga @16"	R-11 Unfaced	None
Panel 7 EIFS	1-1/2"	Mech. Fastened	Grooved EPS	House wrap	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 8 EIFS	1-1/2"	Mech. Fastened	Grooved EPS	House wrap	Plywood	2 x 4@16"	R-11 Unfaced	6 mil Poly
Panel 9 EIFS	1-1/2" Flat	Mech. Fastened	Mat	House wrap	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 10 EIFS Ventilated	1-1/2" Flat	Adhesive	Lath	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 11 EIFS Commercial	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	ASTM C1177 Gyp. Board	18 ga @16"	R-11 Unfaced	None
Panel 12 3-Coat Portland Cement Plaster (Stucco)	None	Mech. Fastened Note 2	3.4 Metal Lath	2 Layers Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 13 1-Coat Portland Cement Plaster (Stucco)	1" Flat	Paint - later date Note 2	Woven Wire Plaster Base 1 x 20 ga.	1 Layer Grade D 60 Minute (behind foam)	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 14 Brick	None	Brick Ties	Air Cavity 1"	1 Layer Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 15 Cementitious Fiberboard Siding	1/2" XPS	Mech. Fastened	NA	1 Layer Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None

Typical Interior Finishing - 1/2" drywall, primed and painted (1 coat acrylic paint)

Note 1: Finished with furred (with 1X2 treated) 1/2" drywall, primed and painted (1 coat acrylic paint)

Note 2: Painted white initially, Plywood = 1/2", OSB = 1/2". Lath = G 60

FIG 7
Interior of NET Facility



FIG 8
Exterior of Southeast Wall NET Facility (Phase 1)



The three innovative EIFS features evaluated in this study are described below:

- Liquid applied water-resistive barrier coatings. These water-resistive barrier coatings are innovative due to the hygrothermal properties they impart and their application characteristics. These materials may be further engineered to provide gravity-assisted flow by modifying the surface tension characteristics of the exterior sheathing, thus water drains more readily. (Figure 9).
- Synchronous exterior and interior wall element moisture management. This technology engineers several elements of wall materials and sub-systems to minimize moisture in EIFS walls. This is achieved by using the most appropriate water vapor transmission, sorption, suction and liquid transport properties for each material in the envelope. In some instances, they are an assembly of materials,
- or subset of an envelope, that optimize the thermal and moisture transport, which results in high drying potential of the walls (Figure 10).
- Ventilated exterior claddings. In these systems, the exterior cladding is intentionally ventilated (open at top and bottom) and drained using one of two options: directly using integrated systems or channeled foam systems, or indirectly using adhesive channels, such as notched trowel, vertical ribbons. A variation of these systems was included in this study to assess unvented, vented (open at the bottom only) and ventilated systems (open at the top and bottom), (not commercially available). Vented systems moderate the air pressure across the exterior cladding, reducing the pressure difference across the cladding, which can reduce exterior air and water from entering the wall system. Ventilation allows air to move freely behind the cladding, which increases the drying potential of walls (Figure 11).

FIG 9
Vertical Ribbons of Adhesive
Drain Efficiently

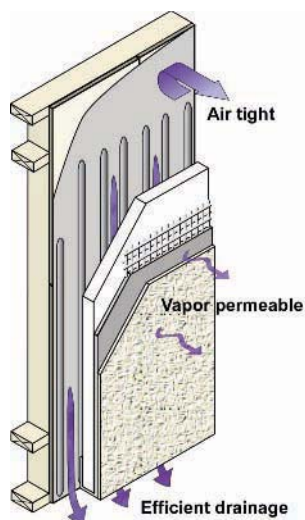
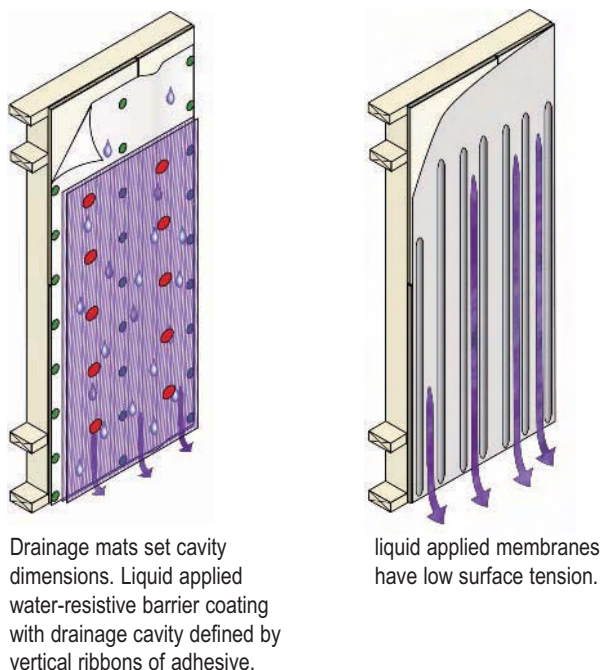


FIG 10
Different Strategies for Drainage



In Phase II, simulated building envelope defects were introduced into some of the wall panels, which included newly constructed wall panels as well as some of the 20-month aged wall panels from Phase I. The goal was to assess the performance of cladding assemblies to water penetration, as well as the impact on the performance of wall systems from wall orientation on moisture infiltration, the type of water-resistive barriers used (sheet membranes versus liquid applied) and different exterior cladding systems (EIFS and brick). In Phase II, wall panels were placed on both the southeast and northwest sides of the building (Figure 12). Table 2 (page 12) lists the configurations of the wall systems studied in Phase II, including on which side of the building the panels were placed. Data were collected from May 2006 to June 2007.

FIG 11
Drying Effect of Ventilation

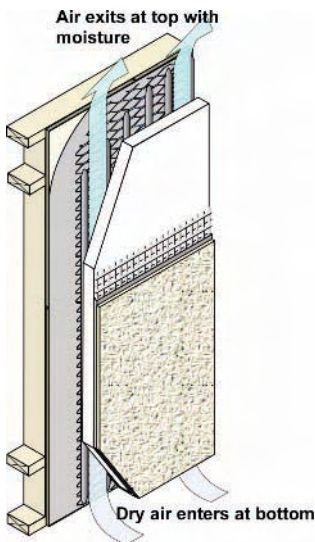
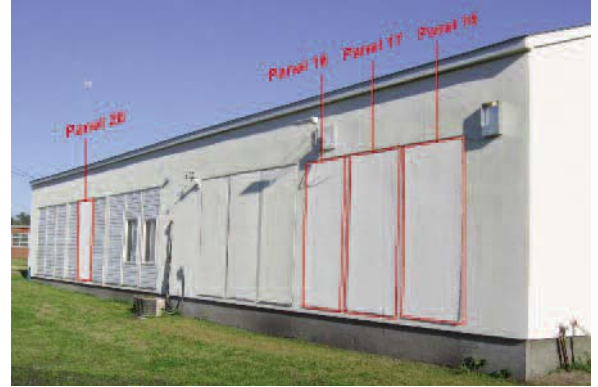
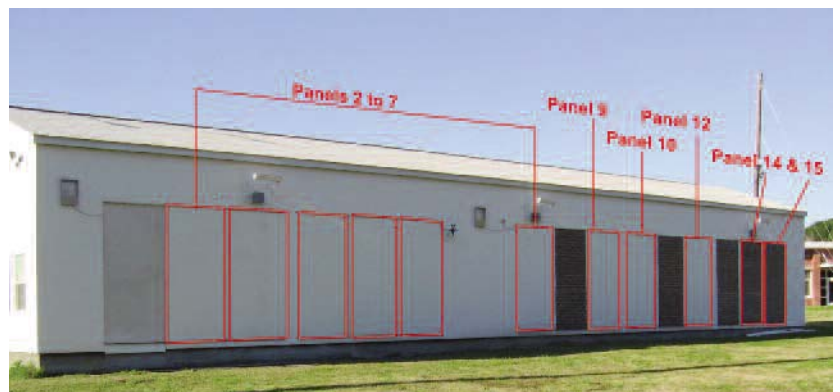


FIG 12
Phase II
Panel Locations



Northwest Wall Panel Location



Southeast Wall Panel Location

Each of the wall panels contained an array of sensors that recorded a full, constant profile of temperature, heat flux, relative humidity, and moisture content. Because of a limited availability of heat flux sensors, the sensors were strategically placed among some of the walls to demonstrate the importance of the rate of heat transfer of exterior insulated wall systems (see “Study Results Underscore Importance of Balance” on page 14 for more information). Table 2 notes which panels had heat flux sensors (HFS).

The sensor placements were identical for all the wall panels (Figure 13), except for relative humidity sensors on panels with absorptive cladding systems (brick and stucco) and non-absorptive cladding systems (EIFS), which were embedded into the exterior cladding on those panels with non-absorptive claddings (Figure 14).

TABLE 2

**Phase II Configuration of the
Exterior Wall Assemblies Investigated**

Panel / Orientation / System / Heat Flux Sensor (HFS)	EPS	Attachment	Drainage / Air Space	Weather Barrier	Sheathing	Framing	Cavity Insulation	Vapor Barrier
Panel 2 , SE, EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 3 , SE With Flaw, HFS EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 4 , SE, EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	6-mil Poly
Panel 5 , SE, HFS EIFS	4" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	None	None
Panel 6 , SE, HFS EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	18 ga @16"	R-11 Unfaced	None
Panel 7 , SE, With Flaw, HFS EIFS	1-1/2"	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	6-mil Poly
Panel 9 , SE, HFS EIFS	1-1/2" Flat	Mech. Fastened	Mech. Fastened	Mat	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 10 , SE Ventilated, HFS	1-1/2" Flat	Adhesive	Lath	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 12 , 3-Coat Portland Cement Plaster (Stucco) SE, HFS	None	Mechanically Fastened	3.4 Metal Lath	2 Layers Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 14 , SE, HFS Brick With Flaw	None	Brick Ties	Air Cavity 1"	1 Layer Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 15 , SE, HFS Brick	None	Brick Ties	Air Cavity 1"	1 Layer Grade D 60 Minute	OSB	2 x 4@16"	R-11 Unfaced	None
Panel 16 , NW, EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	6-mil Poly
Panel 17 , NW, HFS EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 18 , NW, With Flaw, HFS EIFS	1-1/2" Flat	Notched Trowel	Vertical Ribbons	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None
Panel 26 , NW, Ventilated, HFS EIFS	1-1/2" Flat	Adhesive	Lath	Liquid	Plywood	2 x 4@16"	R-11 Unfaced	None

Typical Interior Finishing - 1/2" drywall, primed and painted (1 coat acrylic paint)
SE = Southeast Face
NW = Northwest Face

FIG 13
Placement of Sensors in Panels

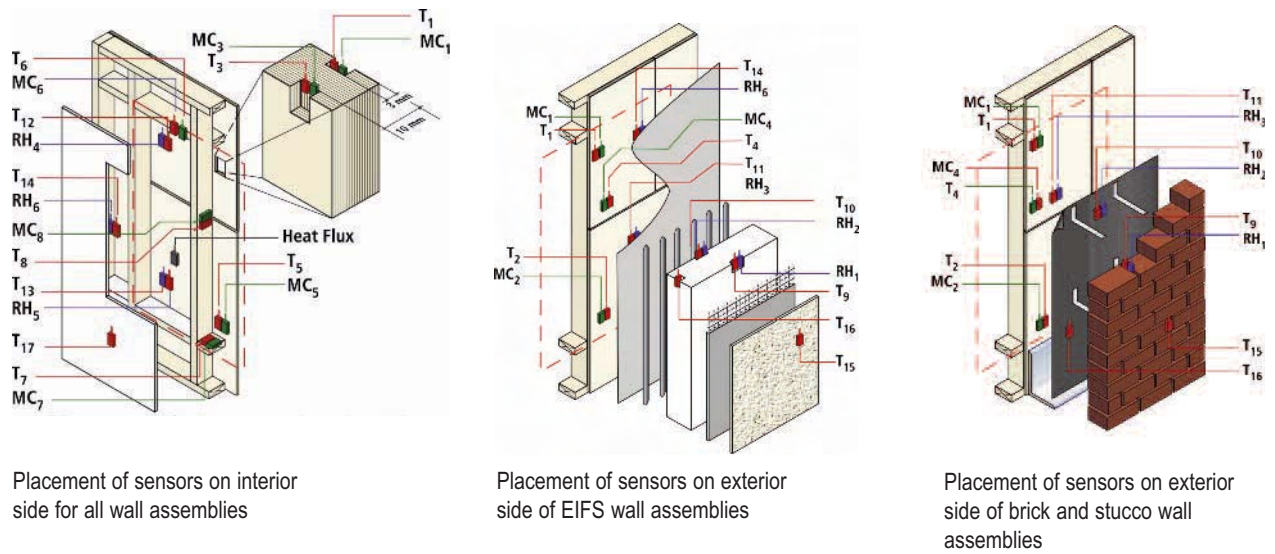
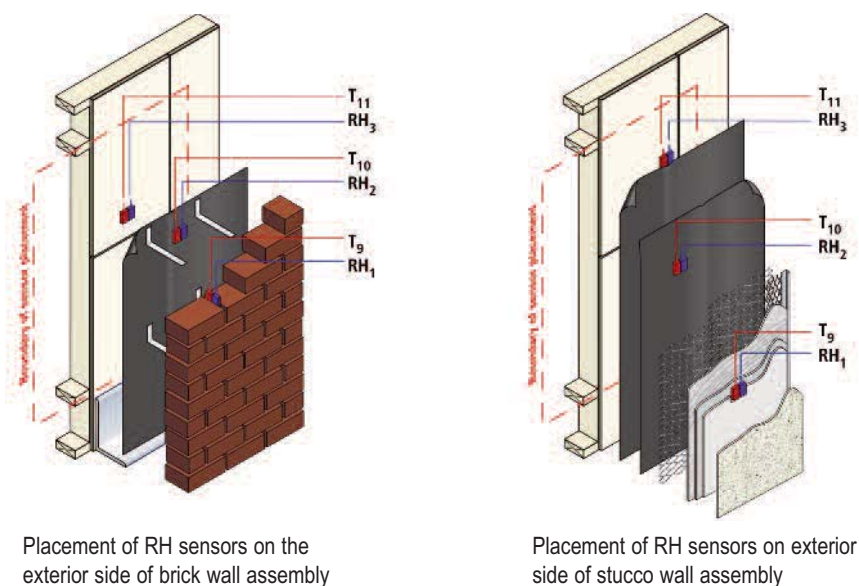


FIG 14
Placement of Relative Humidity
Sensors in Brick and Stucco Panels



Study Results Underscore Importance of Balance

When designed and operating properly, the building envelope responds to both interior and exterior conditions. In an ideal building, the average rate of heat flux (or movement of energy) across the wall system should remain constant at around a value of zero on the interior surface. Likewise, the relative humidity within the wall system should remain low, and temperature within the wall cavity also should remain constant. The closer the heat flux is to zero the smaller the HVAC equipment will need to be to maintain comfortable interior conditions. The following discusses the study results and their implications within the context of the principal performance goals cited above: energy efficiency, moisture and temperature control.

Energy Efficiency

As noted, an ideal energy efficient building would feature a building envelope and wall system that perfectly balances outdoor and indoor air pressures, airflows, and heat and moisture loads. All too often however, problems occur when there is an imbalance. For example, too much heat entering the wall system (positive heat flux) requires a higher cooling load while too much heat leaving the wall system (negative heat flux) has the opposite effect and increases the heating load. As a result, the HVAC system has to work harder and use more energy.

The presence of excess moisture within the building envelope system can also affect energy efficiency. For example, as moisture accumulates, thermal conductivity may increase by a factor of up to three for polystyrene foam insulation, four for high-density fiberglass insulation, and two for red brick (IEA 1996, Dechow and Epstein 1982). Other studies have also demonstrated that moisture infiltration can decrease energy efficiency due to the local evaporation and condensation, while increasing the energy transfer (positive heat flux) across the building envelope by 5 percent to 150 percent of that occurring under dry conditions (Langlais 1982, Hedlin 1983, Kyle and Desjarlais 1994). In wind-driven rain analyses, the presence of wind-driven moisture in wall systems resulted in a 12 percent increase in energy consumption compared with ideal dry conditions (Karagiozis and Salonvaara 1998, Kuenzel 1994).

The heat flux data collected in this study showed a beneficial thermal performance of the exterior foam insulation for walls facing both southeast and northwest during the cooling season. Reductions of not only the total heat flow, but also substantial peak reduction was also noted. These findings demonstrate that walls with exterior foam insulation, regardless of the type of exterior cladding, can offer a significant energy cost savings.

Specifically, the best performing wall configuration with respect to positive heat flux during the cooling months (keeping heat out) was EIFS with a liquid applied water-resistive barrier coating applied behind the EIFS ventilated wall (Panel 10). The second best performing wall configuration was EIFS with a liquid applied water-resistive barrier coating applied behind the EIFS (Panel 6). Panel 9, the mechanically fastened EIFS applied over the spun-bonded, polyolefin water-resistive barrier, ranked third. During the cooling season, the wall configurations with the greater heat flux were those constructed of brick (Panels 14 and 15) (Figure 15, page 16). As might be expected, the brick wall panels performed better in winter with respect to negative heat flux (keeping heat in), as brick mass tends to hold heat gain from solar radiation. The implication for energy efficiency is that mass walls like brick may have limited advantages in a mixed, coastal, Zone 3 climate, as the heating season is typically short and mild. In addition, during the cooling season, the HVAC system would likely have to work harder and use more energy to balance the positive heat flux.

Moisture and Temperature Control

A consequence of excess water vapor within a wall assembly is the increased possibility of condensation on cool surfaces within the wall cavity. Moisture and/or liquid water also can enter the wall system through defects, poor design, and poor installation of interface materials. Uncontrolled moisture migration can result in significant material degradation if not adequately protected. One of the goals of this study was to determine which wall configurations performed best at managing moisture infiltration.

The results indicated that the highest relative humidities occurred near the exterior sheathing and wood framing during the winter months. This result was not unexpected, as insulation in the wall cavity will result in cooler temperatures at the exterior sheathing. In addition, relative humidity tends to increase as the temperature cools. The best performing wall configuration with respect to controlling relative humidity within the wall assembly was the EIFS panel with four inches of insulation (Panel 5) outbound of the sheathing. The wall stud cavity was not insulated and no vapor barrier was installed on the interior (see Figure 16, page 17). Panel 12, the wall configuration with 3-Coat Portland Cement Plaster (stucco), had the highest relative humidity in both summer and winter (Figure 17, page 18). The walls with stucco and brick showed high relative humidities at the insulation/gypsum interface during the winter months (Figure 18, page 19). Interestingly, the EIFS wall panel that faced northwest (Panel 16) had up to 17 percent higher relative humidity at the exterior sheathing as compared with EIFS wall panels that faced southeast (Figure 19, page 20).

To determine how defects in the exterior cladding might affect relative humidity on the sheathing, the researchers introduced a simulated defect ("flaw") into four of the panels. The "flaw" was a 2'-0" (610 mm) standard "K" gutter mounted above the panel that collected rainwater, which drained through a measurement device for deposition onto the water-resistive barrier in the wall assembly. The gutter length was sized 2'-0" in length to match the opening used in ASTM E2273 "Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish System (EIFS) Clad Walls". Each panel with a "flaw" had an identical corresponding panel without a flaw for comparative purposes. The panels with the "flaw" were:

- **Panel 3** (Corresponding Panel 2): EIFS with notched trowel, vertical adhesive ribbons, a liquid applied water-resistive barrier coating, no interior vapor barrier, southeast orientation (Figure 20, page 21, which represents the measured relative humidity on the face of the exterior sheathing).
- **Panel 7** (Corresponding Panel 4): EIFS with notched trowel, vertical ribbon, a liquid applied water-resistive barrier coating, and a 6-mil Poly vapor barrier, southeast orientation (Figure 21, page 22).
- **Panel 14** (Corresponding Panel 15): Brick, vented, southeast orientation (Figure 22, page 23, which represents the measured relative humidity on the face of the exterior sheathing).
- **Panel 18** (Corresponding Panel 17): EIFS with notched trowel, vertical adhesive ribbons, a liquid applied water-resistive barrier coating, no interior vapor barrier, northwest orientation (Figure 23, page 24).

The results showed that introducing the simulated flaw in the EIFS in the southeast and northwest orientations had a small effect on the sheathing relative humidity. Conversely, introducing the flaw in the brick vented system in the southeast orientation had a much larger effect on sheathing relative humidity. The implication is that EIFS layers comprised of vertical ribbons of adhesive and a liquid applied water-resistive barrier coating provided the most effective method for managing bulk water intrusion into the cladding cavity.

The EIFS walls that used a liquid applied water-resistive barrier coating performed better in this study than exterior claddings with sheet type membranes. In addition, EIFS walls with an exterior air space ventilation (that is, open at the top and bottom) performed better than walls with just venting (those open at the bottom only). The wall systems with highest sheathing relative humidity readings were stucco (both 3-coat and 2-coat), followed by brick and cementitious cladding. The results demonstrated that liquid applied water-resistive barrier coatings outperform the other membranes studied, including membranes covered with a mechanically fastened drainage mat.

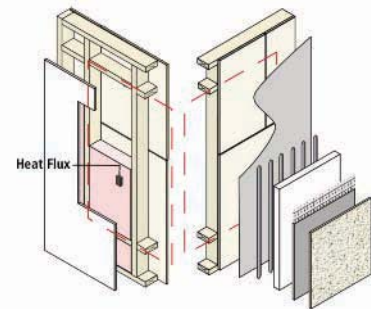
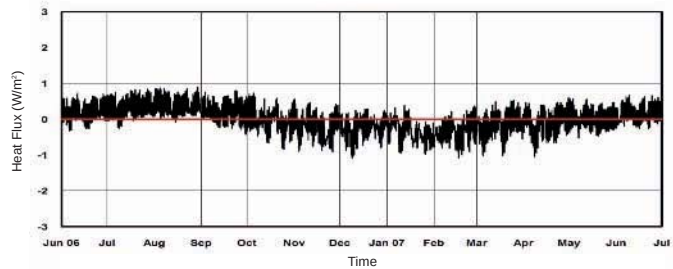
The results also showed that using polyethylene vapor retarders increased the relative humidity by as much as 23 percent on the EIFS wall facing northwest (Panel 17) as compared with the EIFS wall panels facing southeast (Panel 7).

FIG 15

Comparison of Heat Flux Sensor at inside face of interior gypsum wall board in EIFS and Brick Assemblies

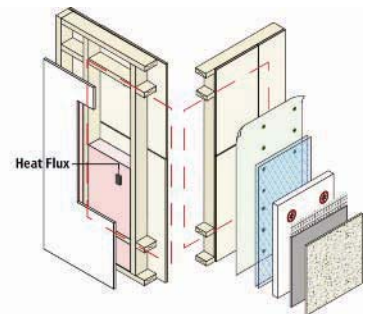
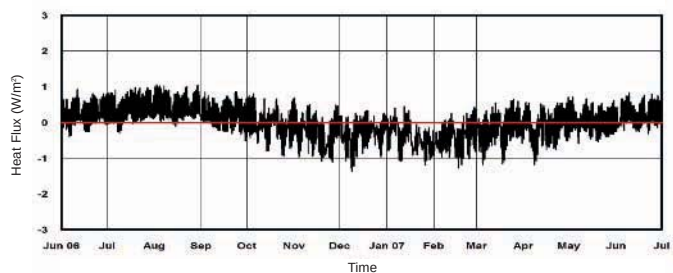
EIFS Panel 6

1.5" EPS plus
batts in stud cavity
Heat Flux Sensor



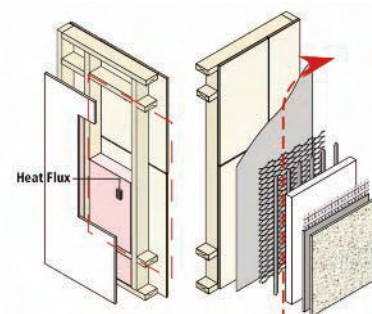
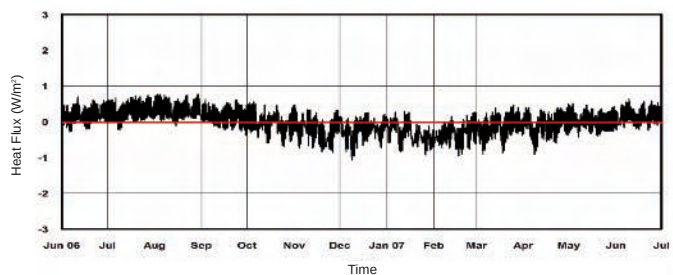
EIFS Panel 9

1.5" EPS with
mech. fasteners
and drainage mat
plus batts in stud
cavity
Heat Flux Sensor



EIFS Panel 10

1.5" EPS lath
ventilated plus
batts in stud cavity
Heat Flux Sensor



Brick Panel 15

Brick ties over
1-layer grade D 60
minute
Heat Flux Sensor

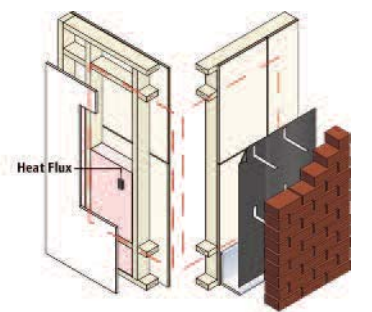
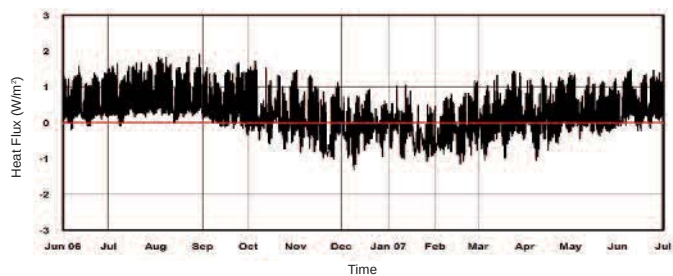
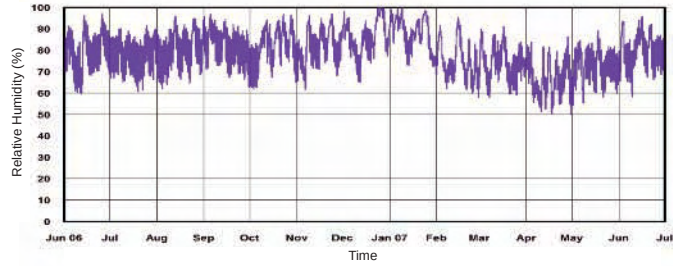
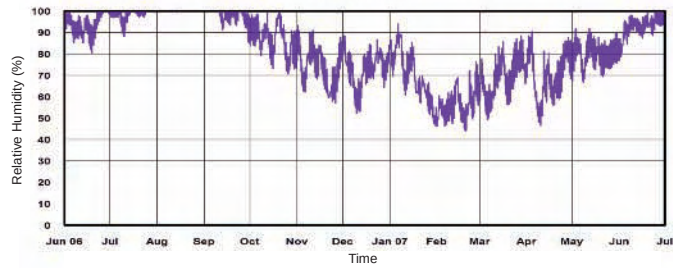


FIG 16
Relative Humidity through the wall in Panel 5

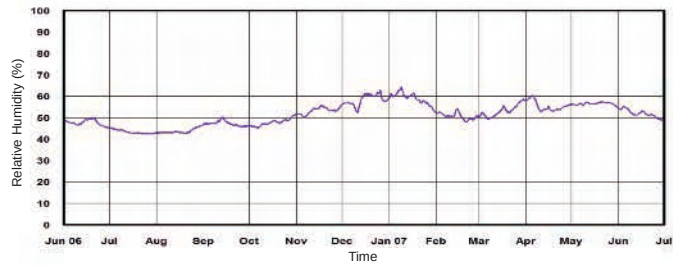
EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 1



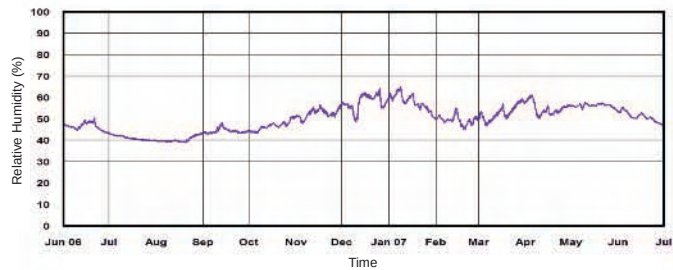
EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 2



EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 3



EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 4



EIFS Panel 5
4" EPS without
batts in stud cavity
Sensor RH 5

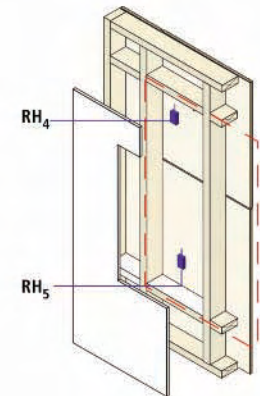
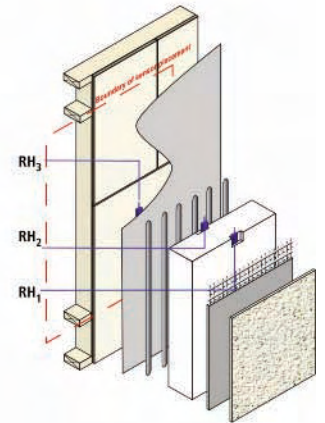
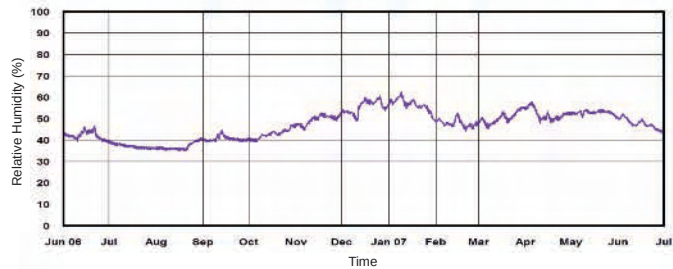
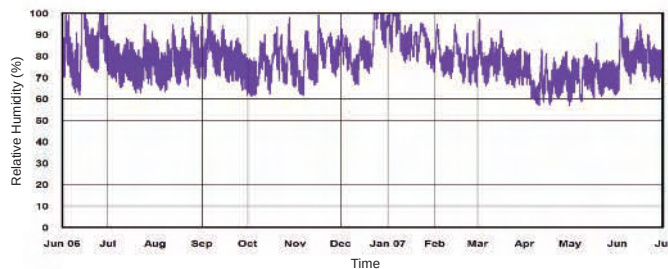


FIG 17

Relative Humidity through the wall in Panel 12

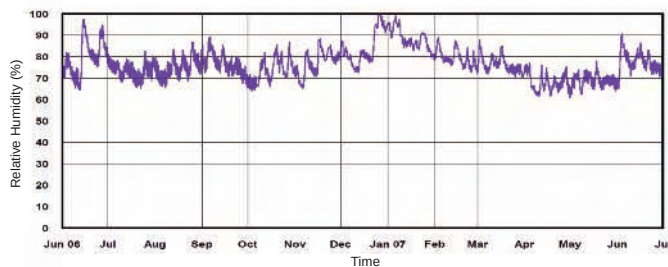
Stucco Panel 12

Metal lath over
2 layers grade D
60 minute
Sensor RH 1



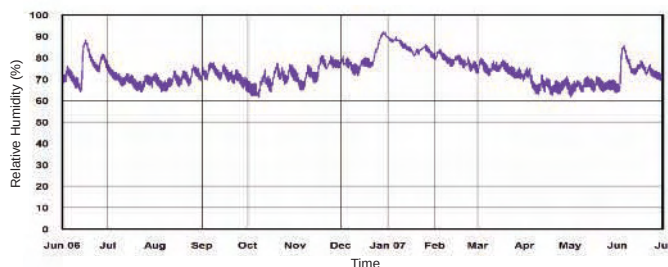
Stucco Panel 12

Metal lath over
2 layers grade D
60 minute
Sensor RH 2



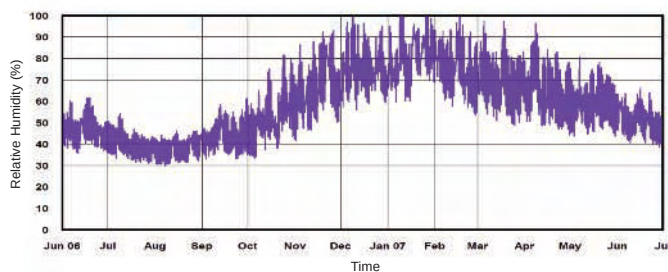
Stucco Panel 12

Metal lath over
2 layers grade D
60 minute
Sensor RH 3



Stucco Panel 12

Metal lath over
2 layers grade D
60 minute
Sensor RH 4



Stucco Panel 12

Metal lath over
2 layers grade D
60 minute
Sensor RH 5

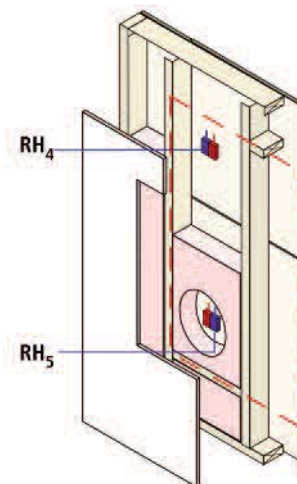
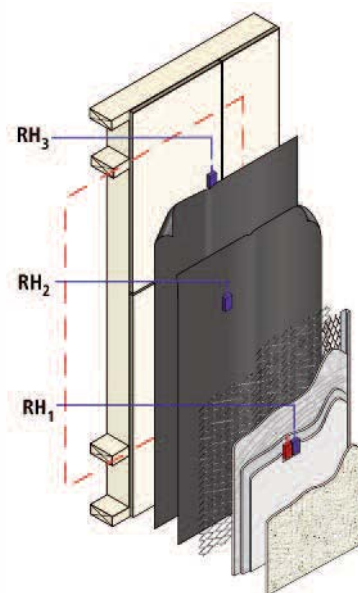
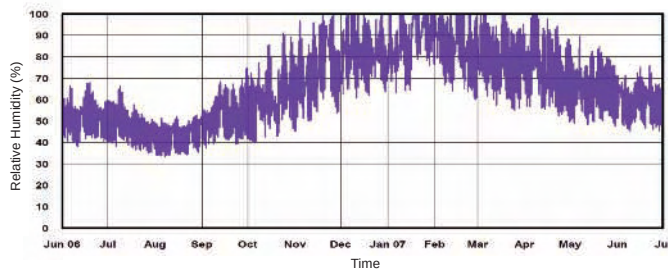
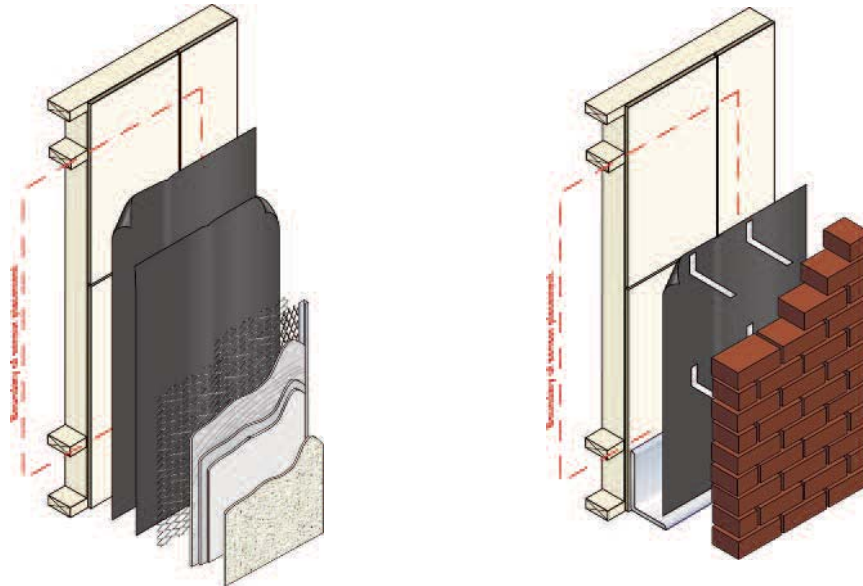
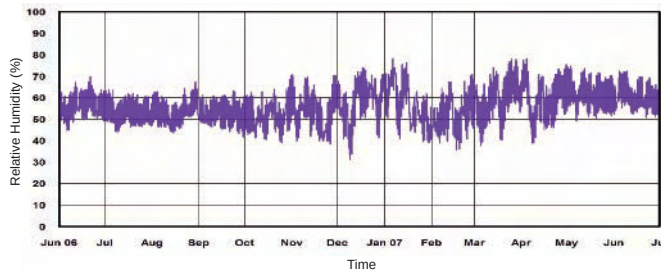


FIG 18
Relative Humidity at interface of interior gypsum wall board and insulation in Stucco and Brick



Stucco Panel 12
 Metal lath over
 2 layers grade D
 60 minute
 Sensor RH 6



Brick Panel 15
 Brick ties over
 1 layer grade D
 60 minute
 Sensor RH 6

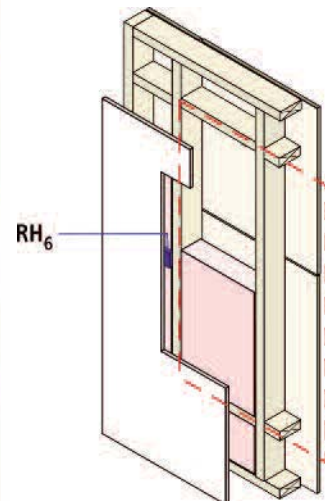
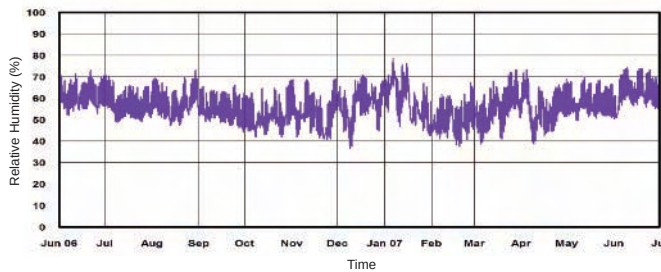
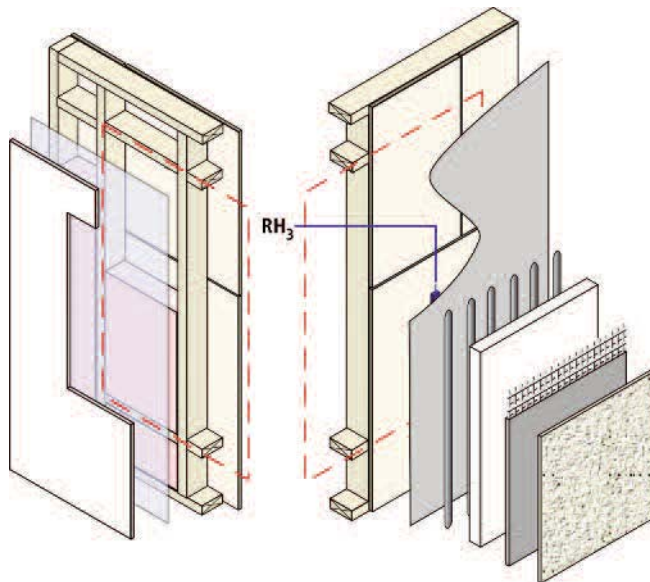


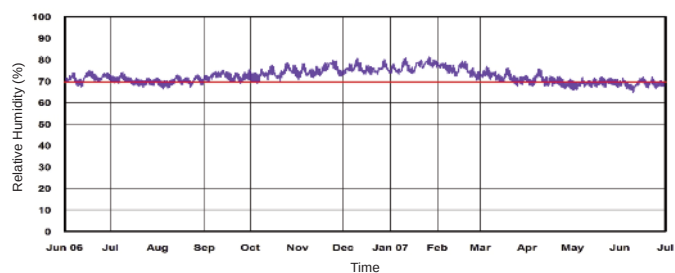
FIG 19

Comparison of Relative Humidity Sensor 3 for EIFS
Panels 4 and 16 from the NW and SE sides of the
facility. Panels constructed with a vapor barrier.

EIFS Panel 4
and Panel 16
1.5" EPS plus
batts in stud cavity
Sensor RH 3



EIFS Panel 4
SE exposure
Sensor RH 3



EIFS Panel 16
NW exposure
Sensor RH 3

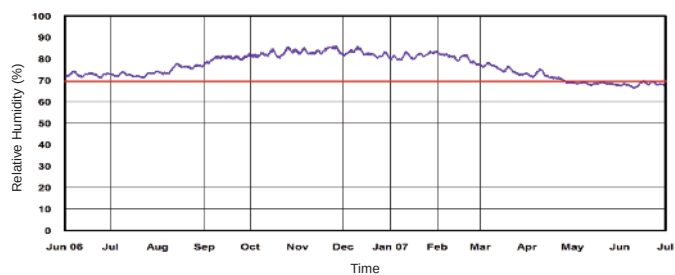
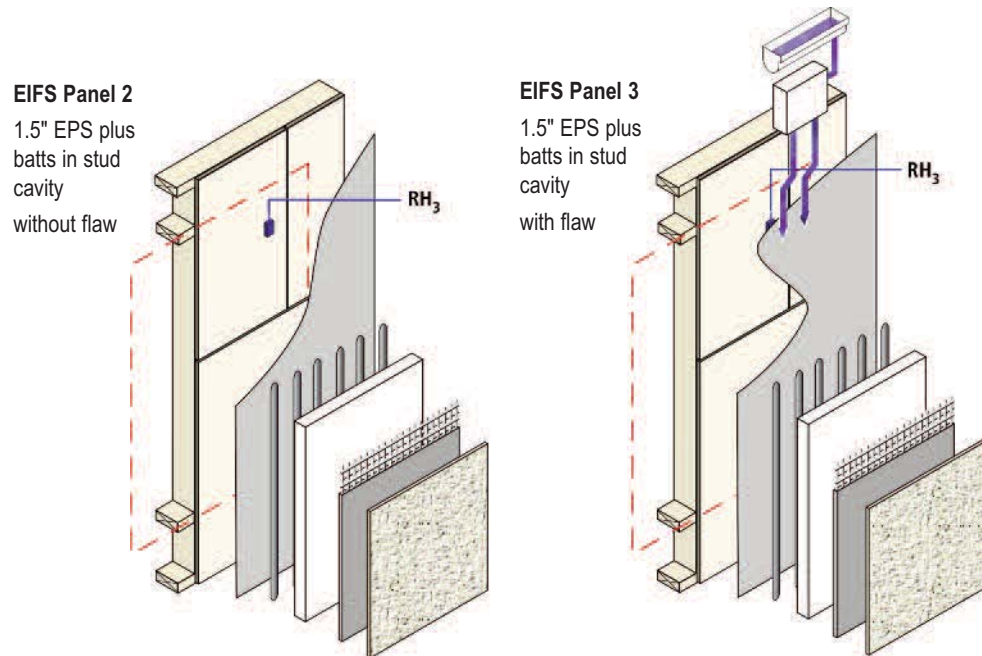
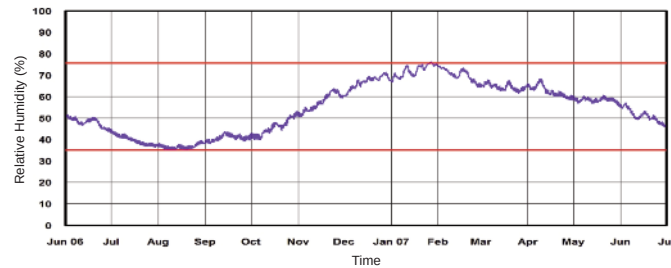


FIG 20

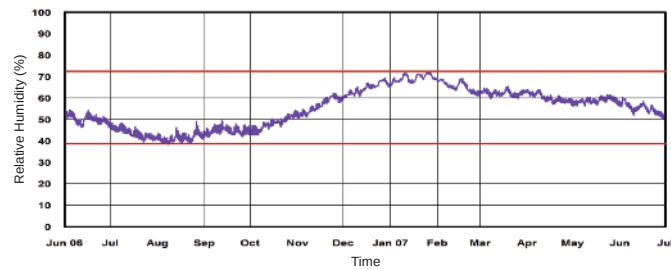
Comparison of Relative Humidity sensors (RH3) installed behind the liquid applied water-resistive barrier coating on EIFS panel 2 (without flaw) and EIFS panel 3 (with flaw)



EIFS Panel 2
no flaw
Sensor RH 3



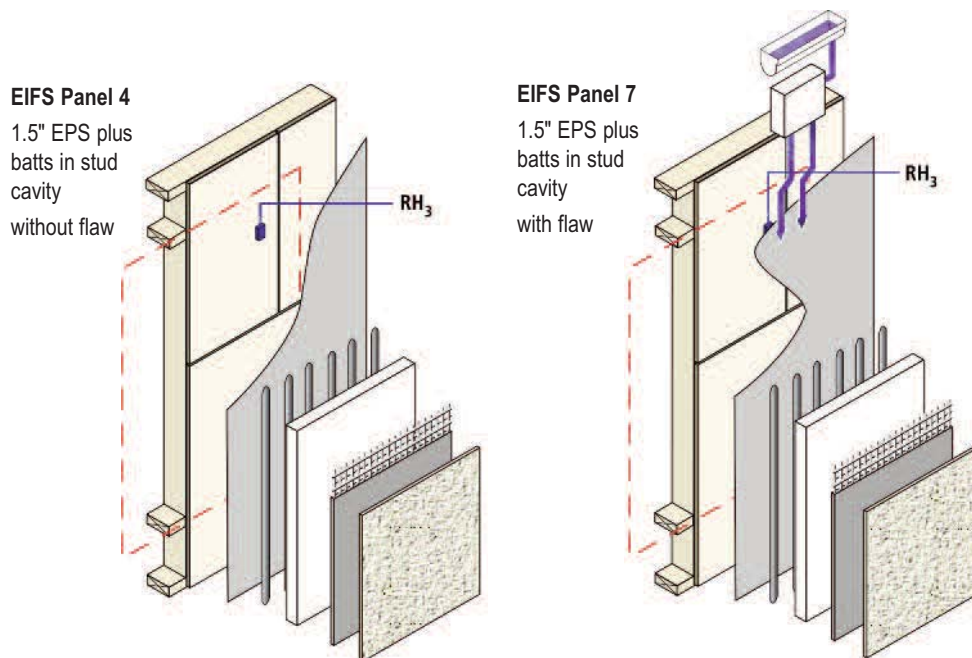
EIFS Panel 3
flaw
Sensor RH 3



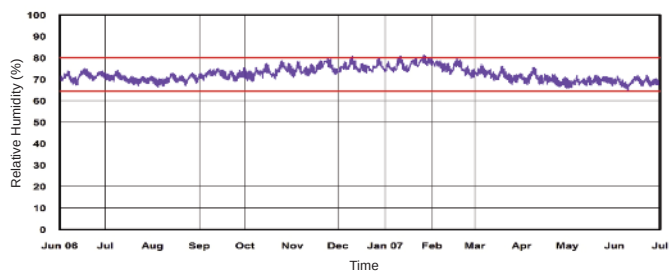
"Flaw" - 2' gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB

FIG 21

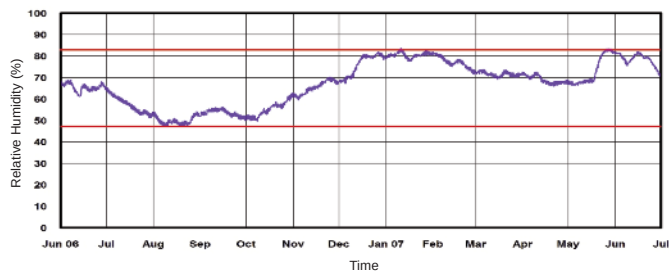
Comparison of Relative Humidity sensors (RH3) installed behind the liquid-applied water-resistive-barrier coating on EIFS panel 4 (without flaw) and EIFS panel 7 (with flaw). A 6-mil poly-vapor barrier is used on the interior.



EIFS Panel 4
no flaw
Sensor RH 3



EIFS Panel 7
flaw
Sensor RH 3

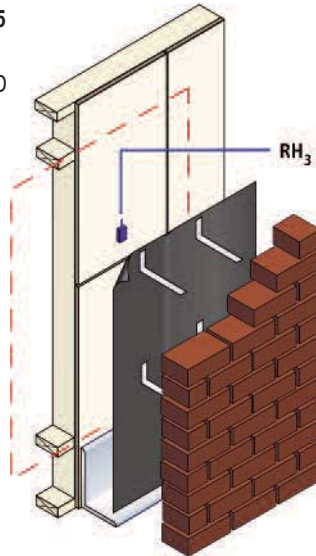


"Flaw" - 2' gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB

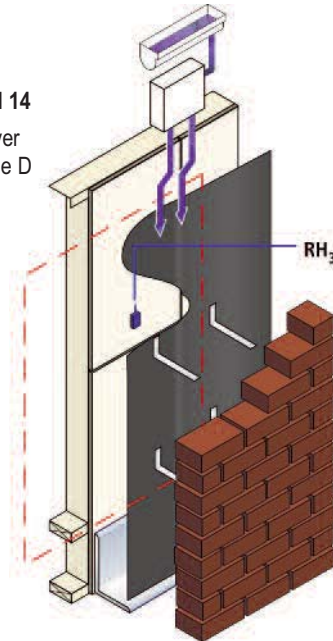
FIG 22

Comparison of Relative Humidity sensors (RH3) installed behind 1 layer grade D, 60-minute water-resistive barrier on Brick panel 15 (without flaw) and Brick panel 14 (with flaw)

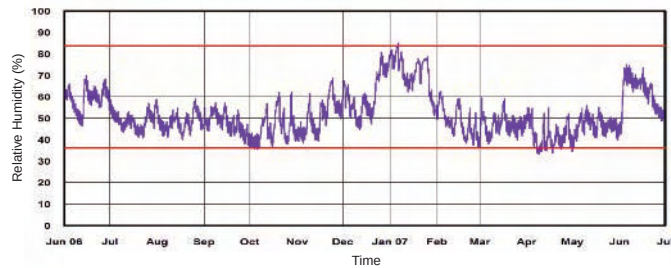
Brick Panel 15
Brick ties over
1-layer grade D
60 minute
without flaw



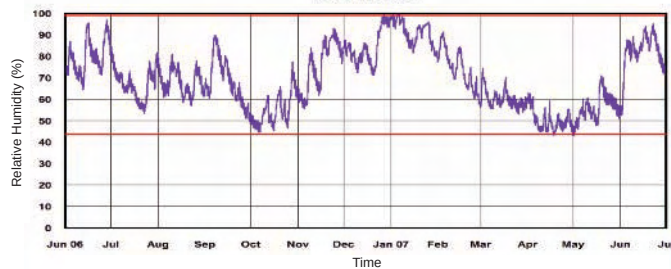
Brick Panel 14
Brick ties over
1-layer grade D
60 minute
with flaw



Brick Panel 15
no flaw
Sensor RH 3



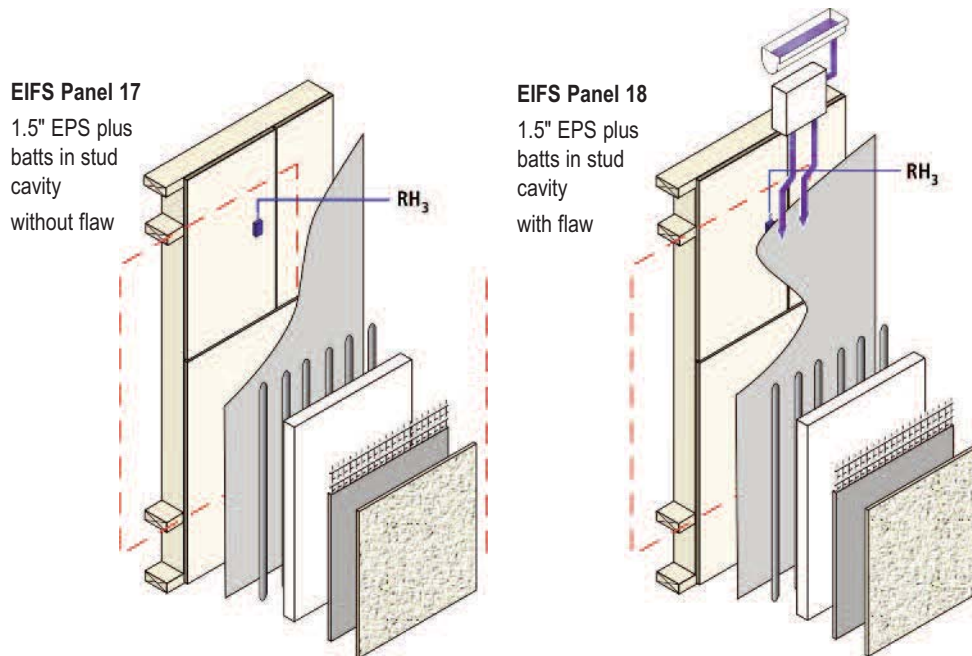
Brick Panel 14
flaw
Sensor RH 3



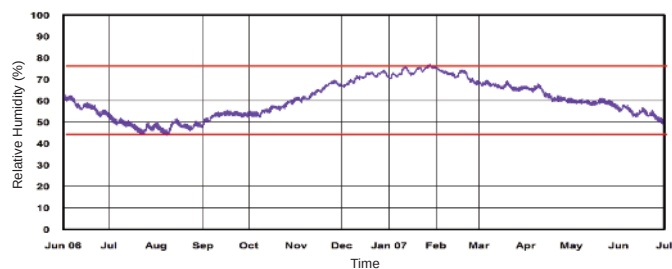
"Flaw" - 2" gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB

FIG 23

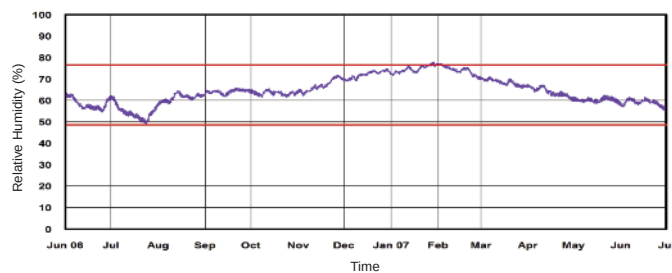
Comparison of Relative Humidity sensors (RH3) installed behind the liquid applied water-resistive barrier coating on EIFS panel 17 (without flaw) and EIFS panel 18 (with flaw)



EIFS Panel 17
no flaw
Sensor RH 3



EIFS Panel 18
flaw
Sensor RH 3



"Flaw" - 2' gutter catches rain water and drains, via a tip-bucket measuring device, onto the WRB

EIFS an Excellent Choice for Mixed, Coastal Zone 3 Climates

The results of this study show that EIFS are capable of controlling temperature and moisture within the wall system and outperform other exterior claddings during the monitored year. In essence, EIFS have the ability to maintain an acceptable balance of moisture and temperature control that is indicative of a well-designed, properly operating energy efficient building without moisture problems.

All of the wall configurations evaluated in this study performed satisfactorily. This study convincingly proves that EIFS is an excellent choice for achieving key building performance goals, including energy efficiency, moisture and temperature control. EIFS absorbs less moisture and heat as does brick and stucco. These results clearly and convincingly demonstrate the superior performance of EIFS in a mixed, coastal, Zone 3 climate.

A complete report on both Phase I and Phase II is available at the Oak Ridge National Laboratory web site:

<http://www.ornl.gov/sci/roofs+walls/research/EIFS/eifs.htm>

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