

## **Commissioning the Building Envelope: Surviving Hurricanes Charley, Frances, and Jeanne**

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### **Synopsis**

In March 2004, the U.S. Army Community & Family Support Center (USACFSC) opened a new 299-room hotel expansion at the Shades of Green® on the WALT DISNEY WORLD® Resort campus. Six months later, in August and September 2004, Hurricanes Charley, Frances, and Jeanne struck the resort, with top wind speeds over 90 mph, and total rain from the three storms in excess of 14 inches. While the existing portions of the hotel and other facilities in the area suffered severe water/wind damage, the new hotel expansion did not have any identified water intrusion.

This success can be attributed to the planning implemented by USACFSC during the initial phases of the design process, and the combined efforts of the owner, commissioning manager, design team, and contractors involved in construction of the building envelope. This paper focuses on the building envelope commissioning activities implemented during the expansion project to maintain a moisture-free hotel. Commissioning activities included peer reviews of the building envelope drawings during each design stage, which focused on the envelope's ability to resist moisture intrusion and also act as an air barrier. During the construction process, multiple tests were performed to inspect and rigorously test the envelope system, thus optimizing its performance.

### ***About the Authors***

R. Bruce Parzych is a Senior Project Manager with The U.S. Army's Community & Family Support Center, Construction Directorate in Alexandria, Virginia. Mr. Parzych was the Army's Project Manager for the \$70-million expansion at Shades of Green® on WALT DISNEY WORLD® Resort. Mr. Parzych has also been involved with other hotel-related projects for the U.S. Army, including the \$100-million expansion of the Hale Koa Hotel in Honolulu.

David MacPhaul, P.E., is a Senior HVAC Engineer at CH2M HILL with nearly 20 years experience in forensic building investigations, indoor air quality consulting, and expert testimony regarding buildings with moisture- and mold-related problems. Mr. MacPhaul manages commissioning projects for HVAC and building envelope systems for hospitality, institutional, and commercial buildings to assist owners with identifying problems before they occur.

## Introduction

In 2000, when The U.S. Army Community & Family Support Center (USACFSC) began discussions about a major expansion (500,000 square feet) to their Shades of Green® on WALT DISNEY WORLD® Resort in Florida, one of the first items addressed was the development of a plan to avoid the mold disaster they had suffered when they opened their Hale Koa Hotel expansion in 1995. Even before guests began occupying the \$40 million, 398-room addition on Waikiki Beach in Honolulu, Hawaii, hotel staff noticed “pink spots” behind vinyl wall covering. After an extensive forensic investigation, USACFSC spent \$6.5 million remedying mold and correcting moisture problems in the new tower. Ultimately, it was discovered that had the fix been applied during the design or construction phase, the cost to the hotel would have been about \$50,000 to prevent these problems.

Therefore, when thinking about the addition to Shades of Green, USACFSC immediately wanted a plan to ensure that no moisture- or mold-related problems would occur in the new hotel. And, although the cause of the moisture and mold problems at the Hale Koa Hotel was related primarily to heating, ventilating, and air conditioning (HVAC) system deficiencies, the torrential rains and high humidity conditions of central Florida prompted USACFSC to focus on the building envelope system. These types of weather-related conditions had caused water intrusion around the sliding glass doors and the growth of mold on interior walls of the existing hotel facility.

USACFSC retained CH2M HILL to perform design- and construction-phase commissioning for HVAC system, electrical system, and the building envelope. This paper focuses on the building envelope commissioning activities implemented by USACFSC and CH2M HILL to maintain a moisture-free hotel, which would ultimately weather three severe hurricanes (Charley, Frances, and Jeanne) within 6 months of opening. As shown in Exhibit 1, the eye of each hurricane passed within 50 miles of the Shades of Green®, so the facility experienced some of the most intense conditions that these storms offered. Conditions included high winds, up to 90-mile-per-hour (mph) wind gusts, and tremendous amounts of rainfall in short time periods (averaging 5 inches for each hurricane).

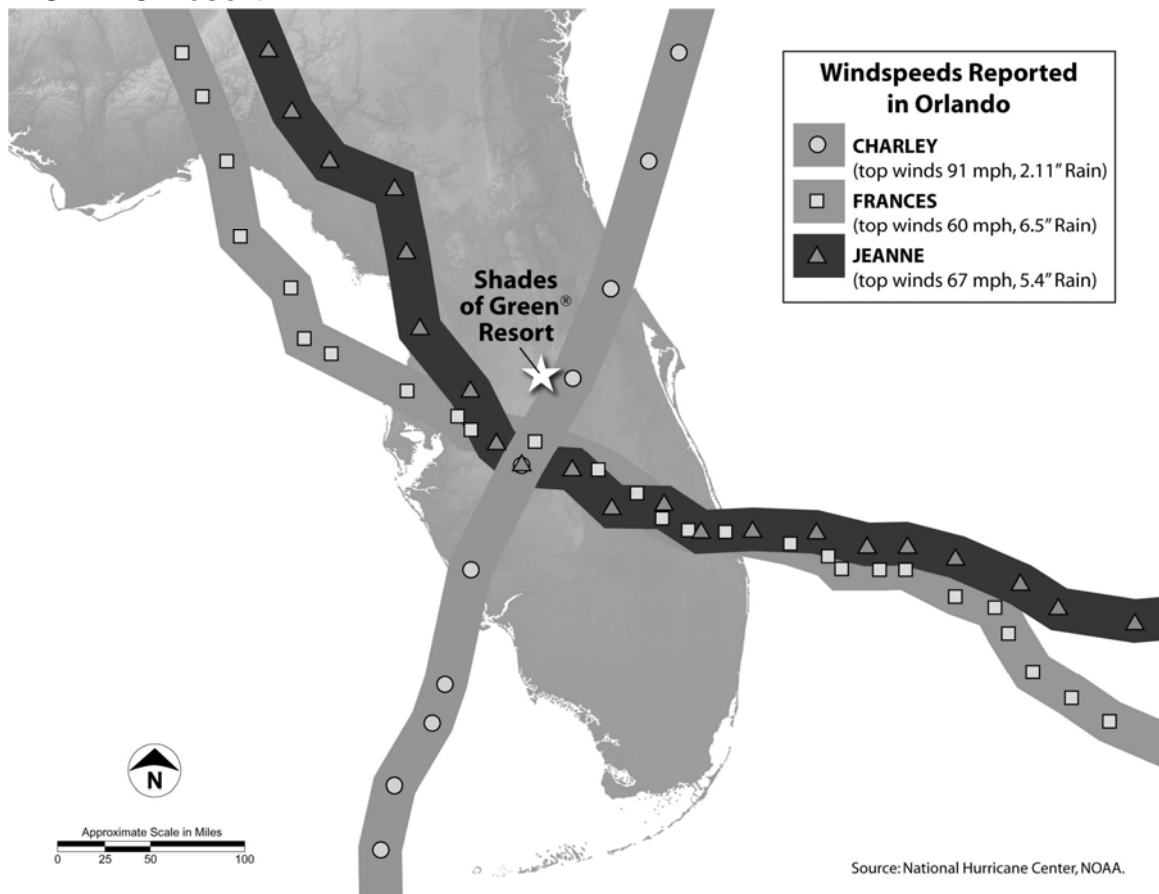
### ***Building Envelope Failures***

When it comes to remaining dry, many new buildings fail to perform as well as expected. In fact, according to the Construction Specification Institute, envelope leaks were the number one cause of lawsuits against design architects in 1999. This may occur because the architect is primarily focused on meeting the owner’s intent with respect to the building use and overall aesthetics of the project. And, once construction starts, the contractor is primarily focused on the construction of the building as shown on the drawings within the schedule and budget of the project. The role of the envelope commissioning manager (CxM) is to maintain the team’s focus on the critical weather, vapor, and air barrier roles of the envelope.

In general, some of the key drivers behind envelope failures include:

- Reliance on a single rainwater barrier
- New untested building materials
- Complex geometries
- Repetitiveness of problem details
- Lack of technical understanding of moisture intrusion mechanisms
- Lack of understanding of inter-relationship with HVAC systems
- Lack of modeling/review/testing/startup

**Exhibit 1: Three hurricanes passed across central Florida in August and September of 2004, bringing high winds and torrential rain, which significantly tested the building envelope at the Shades of Green® on WALT DISNEY WORLD® Resort.**



### ***Building Envelope Commissioning is New and Complex***

Even with the large number of problems with moisture intrusion in buildings, commissioning of the building envelope is a relatively recent process compared to the commissioning of the HVAC system in buildings. ASHRAE Guideline 1-1996 *The HVAC Commissioning Process*, has been in place for almost a decade to help engineers and owners properly design, construct, and test

HVAC systems in buildings. Currently, there are **no** similar guidelines for commissioning the building envelope.

As a process, commissioning the building envelope is much the same as commissioning the HVAC system; design-phase peer reviews and construction-phase inspections follow a similar pattern. However, for the building envelope, there is typically nothing comparable to the test and balance and other functional test procedures that are routinely specified in contract documents for HVAC systems. This paper focuses on ways in which the envelope commissioning process differs from the HVAC commissioning process, and describes steps that are needed to ensure the success of the envelope commissioning.

### ***Implementing Envelope Commissioning at Shades of Green***

The commissioning process began while the design team was preparing schematic design documents. As always, the earlier the commissioning process begins, the easier it is to incorporate the commissioning comments into the construction documents. The following commissioning process occurred for each system commissioned (building envelope, HVAC system, and electrical system):

Design Phase	Commissioning Workshop Peer Reviews/Adjudications Value Management Workshop Constructability Reviews Commissioning Specifications
Construction Phase	Commissioning Workshop Review of Submittals and Substitutions Onsite Inspections Functional Performance Testing
Post-Occupancy Phase	Functional Performance Testing

### **Design-Phase Commissioning of Building Envelope**

To kick-off the commissioning process, the CxM conducted a commissioning workshop with the design team members to discuss what items were to be commissioned and how the process would work. In this meeting, it was stressed that the function of the commissioning team was not to review all items related to the design and construction of the hotel, but to focus on specific key items in the building envelope design and construction known to allow moisture intrusion.

In addition, it was stressed at this workshop that design phase commissioning would not slow the design process; all peer reviews would occur within the timeframe of the originally scheduled owner reviews. Finally, it was re-iterated that the design team had the final say, as they were ultimately responsible for signing and sealing the construction documents.

For the building envelope, several items were focused on to prevent moisture intrusion problems. These included the sliding glass doors, which in the CxM's experience with renovating hotels in

the Orlando area, had proved to be significant problems in a number of hotels. In fact, at the existing hotel building at Shades of Green®, rainwater intrusion around the sliding glass doors was a problem the hotel had grappled with for 5 years.

A related focus was the role of the building envelope as an air barrier. The building was designed for the HVAC system to provide positive pressure in the hotel to prevent the infiltration of humid outside air into the building. For the HVAC system to work properly, the envelope system had to be relatively air-tight. The building envelope reviews examined how the wall systems and fenestration would function together to form the air barrier.

Design phase peer reviews were conducted on the 100% Schematic Design documents, the 100% Design Development, and the 30%, 60%, and 90% Construction Documents. Review comments and suggestions were provided to the design team for their comments. Exhibit 2 provides an example of the comments provided. Comments were broken down into three types to speed the review process. Potential Envelope Failure (PEF) comments reflected items that, based on industry experience, had failed repeatedly. The second type of comment was related to Installation Critical (IC) items. These were construction details which could work, but required that the contractor pay careful attention to the installation to ensure that they would work properly. Finally, alternative considerations (AC) were recommended, which were items that might improve function or reduce construction costs.

**Exhibit 2: Representative Comments from the 100% CD Construction Documents, Shades of Green® Expansion, February 2002**

#	Reference	Comment	Type	Reviewer	Recommendations
A-5	A1.05 and Section 2/A12.01	The area between column lines LK to LP and L2 and L6 is located below grade and under Porte Cochere M256. How is this area being waterproofed both at the below grade walls and the roof/ceiling that is below the entry drive at the Porte-Cochere? Has all traffic loading been taken into consideration?	IC	CF	Review design to see if wall and ceiling/driveway areas are properly detailed for waterproofing.
A-6	A1.05 and A2.05	The many of the Level 1 areas surrounding Stair #1 (M230) are below the Level 2 Entry Court area which will have walkways that are exterior but under cover. Some of these walkways are shown to have floor drains which implies that they will be pressure washed and or wet from time to time. Since these areas are either below Stair #1 or the exterior covered walkways there is a concern for how these areas are being waterproofed and insulated to provide an adequate building envelope.	PEF	CF	Review design to make sure waterproofing and thermal barrier details have been incorporated into the design.

After each review, adjudication meetings were held with the owner, design team, and commissioning team to review comments and develop modifications to the drawings where necessary. The comments spreadsheet, as shown in Exhibit 2, was updated to keep track of the

comments and to ensure that the resulting design decisions were incorporated in the next construction document set.

At the end of the Design Development stage, USACFSC and the CxM conducted a Value Management Workshop with the design team and contractor representatives. After this workshop, the commissioning team reviewed the value management concepts, focusing on moisture-control issues. Ultimately, an approximated \$3 million was identified in overall cost savings, without compromising the ability of the structure to resist moisture intrusion and act as an air barrier.

In addition to the commissioning reviews, a constructability review was performed on the 30% and 60% construction documents. A senior construction manager, experienced in the concrete construction being used at the hotel, reviewed the documents and provided comments on the difficulty that a contractor might encounter trying to construct the building as shown on the documents. For the envelope, the construction manager focused on the construction details, pointing out areas where a detail would be difficult to construct or where a simplified detail might work more effectively.

To facilitate the construction phase of the commissioning process and preclude critical commissioning elements from being overlooked, commissioning specifications were prepared. The specifications were written by the commissioning team but integrated into the overall construction documents by the designers, instead of being prepared and submitted to the Contractor as a separate document. Here, differences between the HVAC systems and the envelope system design were apparent. The HVAC designers were familiar with commissioning activities and had many of the required components for commissioning already written into the specifications. However, few envelope commissioning specification requirements were provided by the designers; the majority came from the commissioning team. The commissioning specifications outlined the:

- Critical building envelope systems requiring commissioning
- Mockup/model construction requirements for the envelope systems
- Building envelope functional test requirements
- Contractor participation requirements during testing

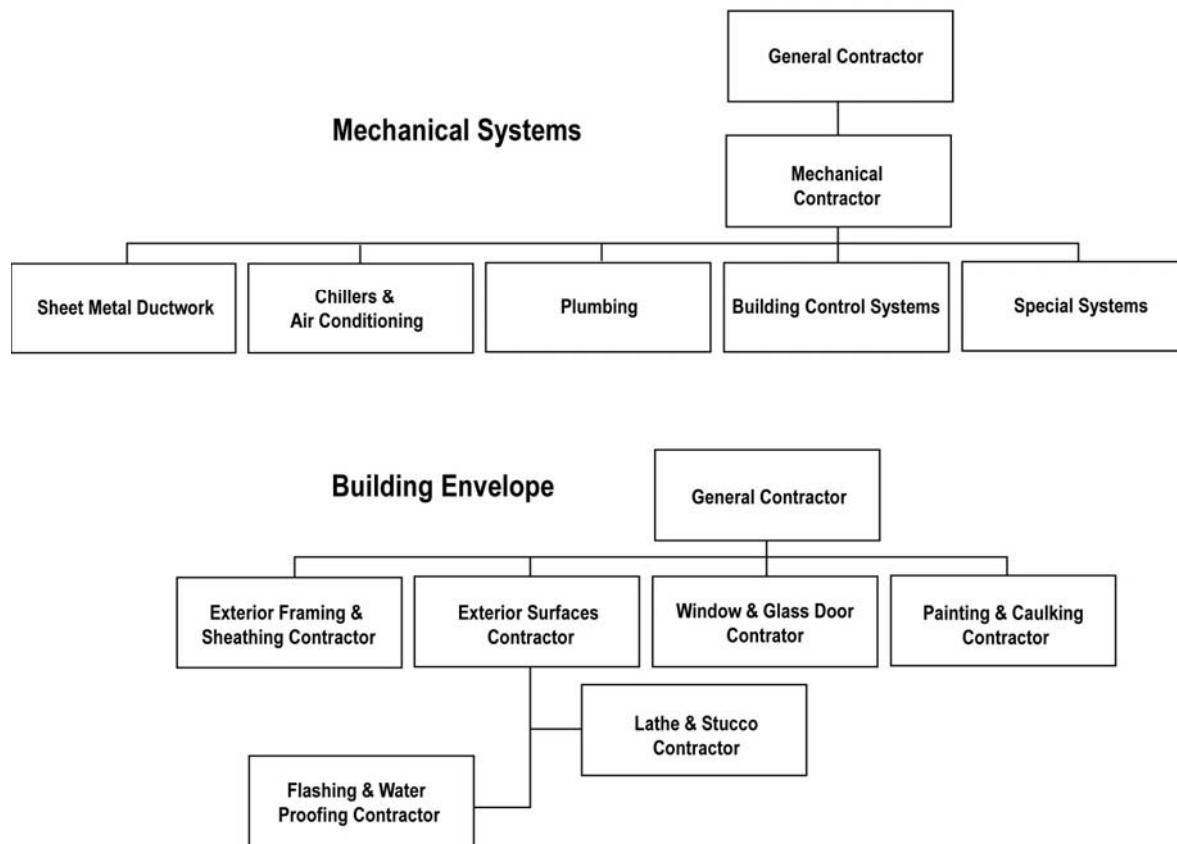
For the building envelope, one goal of the commissioning specifications was to alert the various envelope subcontractors that the envelope would be tested to withstand water intrusion, and that they would have responsibilities for assisting in the testing. Again, in contrast with the HVAC system, where each contractor or equipment manufacturer has had specific startup and testing activities routinely spelled out in the contract documents, the various contractors responsible for envelope construction were not accustomed to seeing these requirements in the contract documents.

## Construction Phase-Commissioning of the Building Envelope

Because the building envelope subcontractors were unfamiliar with the commissioning process, the first step in the construction phase commissioning was to conduct a commissioning workshop. The general contractor (GC) and the subcontractors for the various components of the building envelope were required to attend. The envelope commissioning plan was explained, and the various inspections and functional test procedures were detailed.

One issue the owner and CxM raised in the workshop was the diffuse responsibilities entailed in the construction of the building envelope. In contrast to the HVAC system, where a single mechanical contractor was responsible for the construction of the entire system and held the contracts for the various subcontractors, most of the envelope subcontractors were directly contracted to the GC. This diffuse responsibility could become an issue if problems arose, as no single entity (other than the GC, who had many other roles to fulfill) was responsible for ensuring that the envelope was constructed properly. Exhibit 3 compares the contractual responsibilities for the HVAC systems and the building envelope.

**Exhibit 3: Comparison of the Contractual Arrangements for the Building Envelope and HVAC Systems Construction, Shades of Green® Expansion**



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A second issue the CxM pointed out in the workshop was the difficulty posed in testing the envelope, because the envelope could not be tested, for the most part, until the entire wall assembly was completed. For example, the water-tightness of the sliding glass door assemblies at Shades of Green® could not be tested until: the framing was complete, the Densglas had been installed, the flashing was in place, the membrane waterproofing installation completed, the door itself in place, the stucco was applied and painted, and sealant work completed. The trades involved in these activities are not typically onsite working at the same time and large portions of the envelope might be partially completed before any deficiencies could be detected by water testing.

## **Testing of Mockup Wall**

Because the wall, door, and window systems had to be completely constructed before the envelope could be tested for water-tightness, a mockup wall was constructed. These wall, door, and window sections then set the standard of quality for the rest of the envelope work. For a hotel, this is made somewhat easier because each room stands as a separate unit; a small defined section of wall can be completed with framing stops on either side. Accordingly, once the concrete floors and sidewalls were in place for the second floor, construction began on several wall sections for guestrooms. The installation of each component of the wall assembly was inspected for compliance with the construction documents, manufacturer's installation instructions, and construction checklists developed by the CxM.

Each component was thoroughly photographed for future reference. The photographic documentation was critical to the success of the mockup of the envelope for setting the standard of quality. Many of the installation details were covered up by the next layer of the envelope. For example, the flashing, as well as other components, was covered by the membrane waterproofing. Without photographs, there would be no way of referring back to the successful installation to determine if deviations were occurring.

The commissioning team reviewed submittals and substitutions to ensure that the moisture control and air barrier criteria were upheld throughout the construction process, and to finalize the functional test procedures for moisture intrusion testing.

## **Testing of Mockup Wall Sliding Glass Door Assemblies**

The guestroom sliding glass door assemblies had been identified at the beginning of the project as an area of concern for water intrusion, causing problems in the existing portion of the hotel. Therefore, a rigorous functional test procedure was developed by the commissioning team, which was based on the following standards:

- Test Method A: AAMA 502-02; Voluntary Specification for Field Testing of Windows and Sliding Glass Doors
- Test Method B: ASTM 1105; Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by

Uniform or Cyclic Static Air Pressure Difference (ASTM 1105 is a reference standard within AAMA 502-02 for water-spray testing field procedures and test apparatus).

The windows and doors were specified in the contract documents to meet the criteria outlined in these standards. For field testing, these tests involve placing of the door or window assembly under a negative pressure from the inside, with water sprayed on the outside at a specified rate and in a specified pattern. Because of the wide variety in types of wall assemblies and sizes of doors, water spray test racks cannot typically be purchased for window and door testing, and in this case, the CxM built a testing assembly based on the requirements detailed in the test standards (see Exhibit 4).

One testing requirement that became critical was how much negative pressure the door assembly was placed under for the testing. The specifications stated the door was to be rated for 10 pounds per square foot (psf) in factory testing, but did not state the field testing requirement. The test standard suggests that 2/3 of the factory standard can be used for field testing, but this is not a rigorous requirement. Based on experience, the CxM believed that testing at 10 psf provided a margin of safety that would allow door system performance to degrade slightly over time while still maintaining water-tightness. The manufacturer and the contractor preferred the tests be conducted at the 2/3 suggestion or 6.7 psf. Ultimately, the mockup doors were tested at 10 psf to help refine the construction checklists, and the remainder were tested at 6.7 psf.

During construction, the owners, construction contractors, the design team, and the CxM partnered together to overcome a number of difficulties related to the sliding glass door installation. These included:

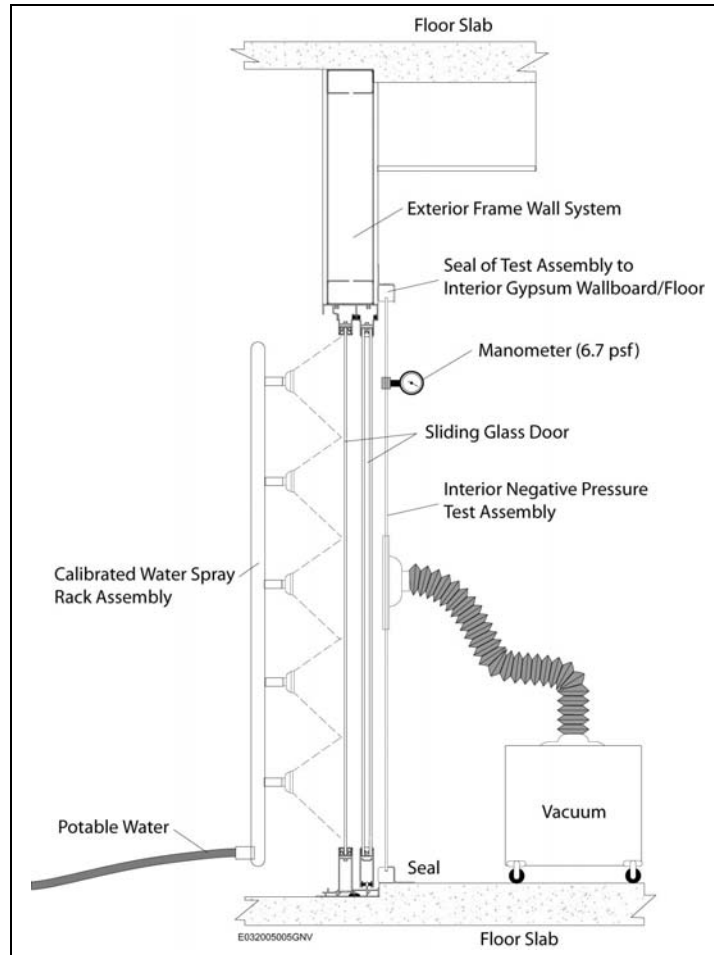
- The sliding glass door frame did not come with the specified nailing flange requiring revisions to construction details.
- Waterproofing details requiring modifications became apparent during the mockup wall construction. Changes were suggested by the CxM and coordinated with the project architects to improve the waterproofing at the sliding glass door frames. The changes were issued to the GC and implemented prior to the start of the formalized sliding glass door testing.
- The sliding glass door unit itself, not the connection between the door frame and the wall, failed during the initial water spray testing.

For the sliding glass door, the first issue in testing was the difficulty in maintaining the door assembly under negative pressure. Smoke tube testing showed large amounts of outside air was entering between the doors and the door frames. The contractor tightened up the assembly, verified seals were in the correct place and that components were mating properly when doors were closed.

When spray testing started, significant water leakage occurred at the door sill with some water leakage through the door head and glazing seals when the door was placed under negative pressure. It became evident from the test results that the doors were failing to meet some of the standards contained in the product literature regarding water intrusion. Throughout this time the

glass contractor was continuing to install frames and door units and with over 300 doors installed or waiting to be installed, time was critical to the success of the sliding glass door installation.

**Exhibit 4: Schematic of the Sliding Glass Door Water Spray Test Assembly, Shades of Green® Expansion**



Working with the manufacturer's installation manual, the CxM, design team, and contractor made modifications to the door installation and conducted additional testing. Of the 12 doors inspected on this second round of testing, seven had the testing immediately discontinued as a result of the large quantity of water leakage that occurred. The primary leakage occurred under the sill jambs and between the door panels. Water leakage at these points may saturate the carpet during heavy rain storm events and render a hotel room non-rentable. Following this second round of test results, the manufacturer came on board and agreed to make the necessary modifications to the doors. Individually each correction made to the door assemblies seemed minor, but collectively the changes improved the performance of the sliding glass doors significantly.

Based on the changes put in place by the manufacturer and the observations made during the installation of the mockup wall assemblies, the original construction phase checklist was refined for the doors and windows in the hotel. Each subcontractor was required to inspect their work using the checklist and sign that it had been completed properly. The CxM, USACFSC, and the GC followed up with random inspections to ensure the contractors were doing the work properly. The commissioning team conducted random water spray testing of an additional 10 doors after checklists were completed and found each one passing at 6.7 psf negative pressure, which was felt to be sufficient to ensure the success of the doors.

## **Air Infiltration Testing**

To determine if the air barrier functions of the envelope were constructed properly, air infiltration testing was conducted on a random sample of guestrooms using a blower door assembly following the protocols detailed in ASTM Standard E779-87, "Test Method for Determining Air Leakage by Fan Pressurization." The blower door testing had not been specified in the contract documents; this testing was primarily done for USACFSC information purposes. The blower door testing and subsequent relative pressure testing done in the hotel indicated the envelope construction was tight, and the HVAC systems in the hotel had no trouble meeting the 5 pascals positive pressurization design goal developed for the HVAC system.

## **Conclusions**

In August and September 2004, Hurricanes Charley, Frances, and Jeanne struck the Shades of Green® on WALT DISNEY WORLD® Resort, with top windspeeds over 90 mph, and total rain from the three storms in excess of 14 inches. While other hotel facilities in the area suffered severe water/wind damage, the new hotel expansion did not have any identified water intrusion.

This extreme weather test indicates why building envelope commissioning is an essential step in ensuring that buildings remain water and air-tight. In a typical building, a window or door installation may be repeated hundreds of times, so failure of a single component can be catastrophic for the building. And, while the commissioning process for the envelope is similar to the commissioning of the HVAC system, there are significant differences. The design-phase commissioning peer reviews, focused on critical success items such as the air barrier and water resistant capabilities of the envelope, follows the same process; however, the construction-phase commissioning is vastly different.

First, building envelope subcontractors are typically not accustomed to performing or assisting with construction-phase commissioning. Next, the building envelope is constructed by a variety of subcontractors, who are generally contracted directly to the GC so no single contractor can be held responsible for the success or failure of the envelope. Finally, the building envelope cannot be tested until all components are in place, but once the components are installed, any necessary modifications to the wall assembly are exceedingly difficult and costly to perform.

To ensure the success of the building envelope, commissioning requirements should be detailed in the specifications, and a commissioning workshop should be held with all the envelope

subcontractors at the start of construction. A mockup wall assembly should be created to allow for inspections and functional testing of the envelope in time for corrections to be made before all wall systems are completed. In the case of Shades of Green®, the assistance of the installing subcontractors and the manufacturer were ultimately required to obtain successful performance of the door assemblies.