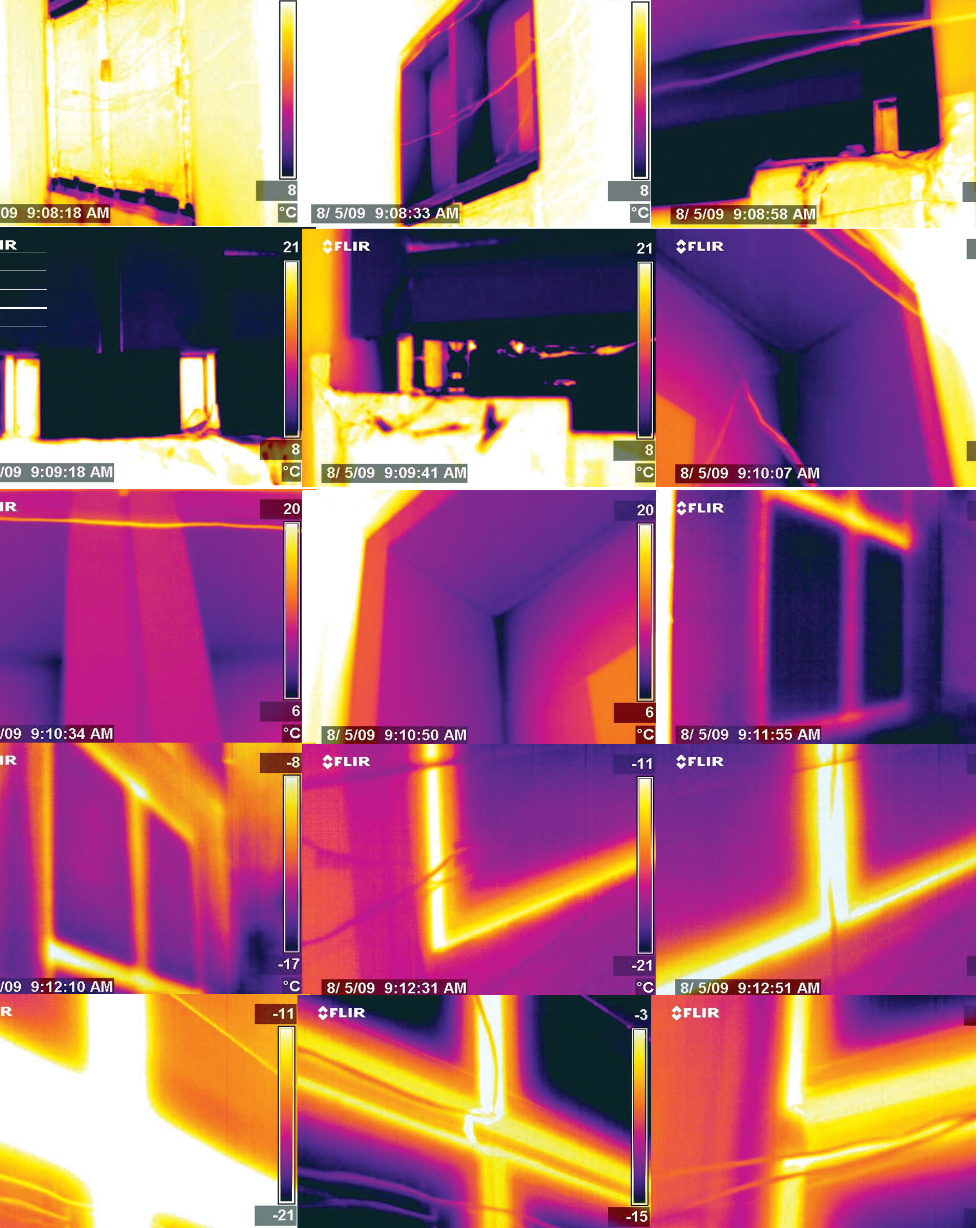


Product Thermal Performance

R&D tests were conducted to evaluate a series of product developments aimed at extending system capabilities to meet increasingly stringent requirements for thermal transmittance and condensation resistance. Specifically the use of composite materials, insulating coatings and various forms of weather sealing were evaluated against a product baseline to determine the merit of each application. Results were used to bench mark computer simulated results and to extend the scope of the analysis by further simulation of untested configurations.

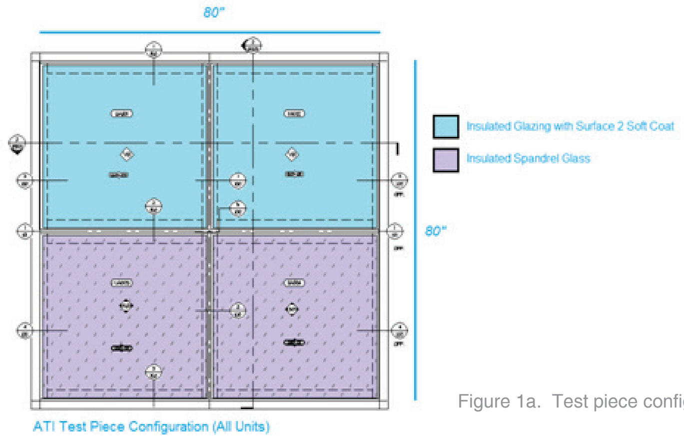


Figure 1a. Test piece configuration.

SPECIFIC SCHEDULE OF TESTS

- Baseline System (Completed December 2009)
- Superior Products "Hot Surface Coat (HSC)" (Completed December 2009)
- Special Composite Polymer (SCP) Edge Protection (Completed December 2009)
- EPDM Gasket Edge Protection (Completed December 2009)
- Temperature Dependence on Weather Seals (Completed February 2010)
- Polymeric Stack Joint Leg (Completed May 2010)

TEST SAMPLES & CONDITIONS

Four test samples were configured to fit the aperture of facilities at Architectural Testing Inc. (ATI) in St. Paul, MN using die shapes from the 246 Spring St. project. The units were square shaped and split into four equal zones by an intermediate vertical and stack joint horizontal. The upper two portions were glazed with 1" IGUs featuring a surface #2 Low-E coating and aluminum spacers. The lower two units were spandrel insulated by 3" of Thermafiber mineral wool insulation. Jamb conditions consisted of split verticals. The upper and lower extrusions of the stack joint were used for the head and sill conditions.

The test procedure used, commonly referred to as a "hot box" test, provides conditions of forced air flow and temperature difference across the sample. Test outputs are the thermal conductance of the unit (U-value), surface temperatures and condensation resistance ratings. For each test the interior side air temperature was 70 F, the exterior temperature was 0 F and the air flow velocity directed against the wall was 15 MPH. These conditions are representative of typical design specifications for northern US climates.

IMPROVEMENTS INVESTIGATED

Superior Products Hot Surface Coat

Coatings can be used to increase interior surface temperatures by either creating an insulating barrier to heat flow or altering the surface in a manner that affects its radiation properties. Hot Surface Coat (HSC) relies on the former characteristic. Applied as an aqueous paste by brush or spray the substance dries and forms a hard coating that is adhesive to most metals. For the test HSC was applied to the non-visible interior surfaces of the stack joint.

Special Composite Polymer (SCP) Edge Protection

Replacement of traditional aluminum alloy fins with Special Composite Polymer (SCP) extruded components significantly mitigates a primary pathway for heat loss in structural sealant glazed systems. Assembly labor is reduced by combining the primary weather seal with the fin and removing the requirement for sealant and backing rod at the glazing interface.

Ethylene Propylene Diene Monomer (EPDM) Gaskets

An alternate replacement for traditional aluminum alloy fins that aims to accomplish the same benefits of SCP with regard to both performance and installation is the use of large EPDM gaskets with blades for both edge protection and outboard weather sealing.

Pultruded Fiberglass Stack Joint Leg

Since the Stack Joint leg that bridges the upper and lower extrusions of the stack-joint assembly is typically a location of low temperature, replacement of that extrusion with a polymeric component has been proposed to increase surface temperatures at that location since it does not play a significant role in the structural load bearing capability of the system. One possibility is the use of pultruded fiberglass, but alternate extruded plastics might also be used. For the test a rapid prototype was developed from ABS plastic using the 3-D printer at ATS.

RESULTS OF INITIAL TESTING FOR THE BASELINE CONFIGURATION

Completion of initial tests indicated that locations typically susceptible to low temperature would have been insufficiently warmed by the traditional methods of isolation employed to withstand condensation under the test conditions and typical project specified humidity. The temperature measured at the interior face of the "chicken-head" was 27 F for the baseline configuration, which is 10 F colder than the

Figure 1b. Mock-up of test specimen.

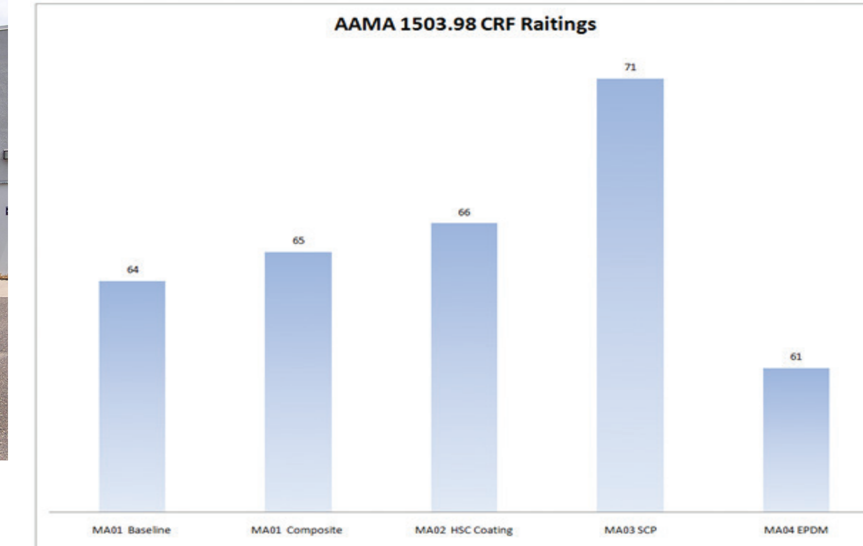


Figure 2. AAMA 1503.98 CRF Ratings.

dew point temperature corresponding to an interior temperature of 70 F and relative humidity of 30%.

EFFECTIVENESS OF IMPROVEMENTS TO MITIGATE CONDENSATION

CRF

The condensation resistance factor (CRF) is a quantitative measure of the resistance to condensation of a system proposed by the American Architectural Manufacturers Association (AAMA). A high CRF rating implies that the interior frame and glazing are close to the interior temperature under the specified exterior conditions of 0 F and 15 MPH impinging airflow. The CRF ratings for each improvement tested are indicated. Typical curtain wall system values range from 60 to 70 for thermally improved systems and the results of the test were within this range. The low performance of the EPDM system was due primarily to failure of the gaskets employed to properly seal against airflow. On the other end of the performance spectrum the SCP fins effectively employed the intended principle by properly maintaining their seal. The CRF performance of the SCP and composite chicken head were not substantial with respect to the baseline configuration, because the improvement was specific to a single location.

Limitations of CRF and Actual Temperatures

While CRF is the sole metric for condensation resistance in some performance specifications a zero to 5% level of observed condensation is more commonly specified under a set of provided conditions. In this case the entire system must be evaluated to assure that temperatures of all surface components to the interior side of the weather barrier are greater than the dew point temperature of the interior air. Traditionally, the stack-assembly provides the greatest design challenge due to the fact that its capability to absorb movement of the curtain wall leads to large areas of exposed metal within the interior of the frame and multiple pathways for heat flow that are not easily mitigated. While the impact to CRF of the HSC coating and composite chicken head were not significant, those improvements are more effective in dealing with this specific issue. Under similar design conditions the implementation of the composite chicken head resulted in a 10 F increase in surface temperatures. The effectiveness of the HSC was on the order of 3 F.

EFFECTIVENESS OF IMPROVEMENTS TO REDUCE U-VALUE

For each test sample the U-value was calculated in accordance with NFRC procedure 102 for measuring the thermal transmittance of fenestration products. While the samples do not conform to the standard product size used for energy ratings, they do provide some indication of system performance. The results of these tests are also outlined. As with the case for CRF the system using SCP fins featured the best performance and the EPDM gaskets performed the worst.

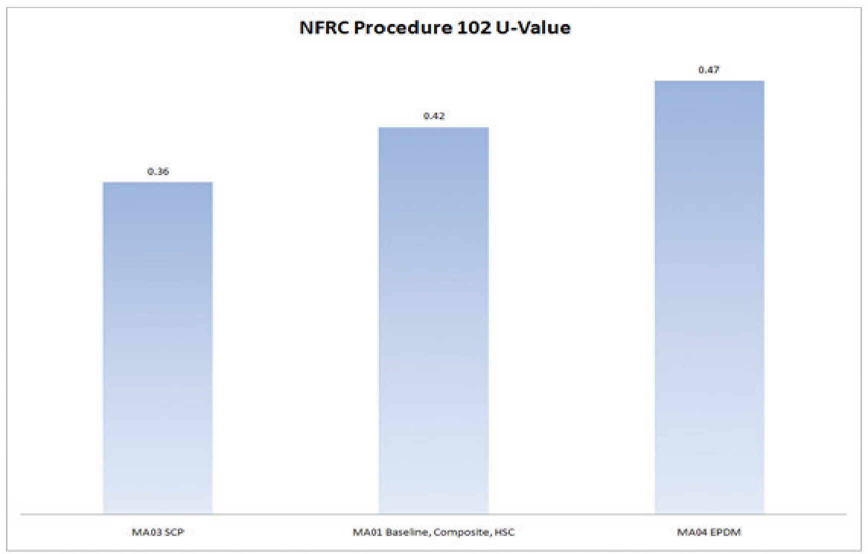
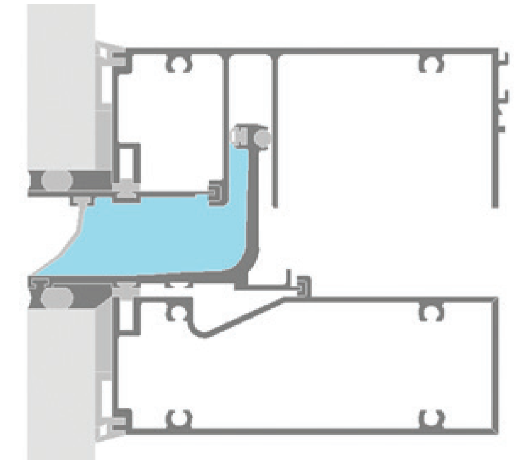
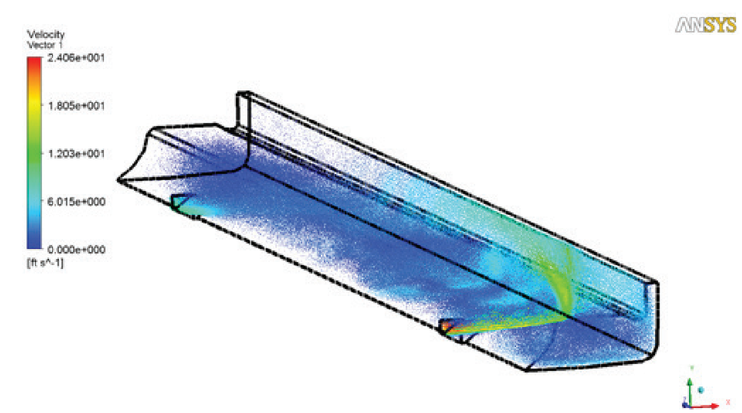


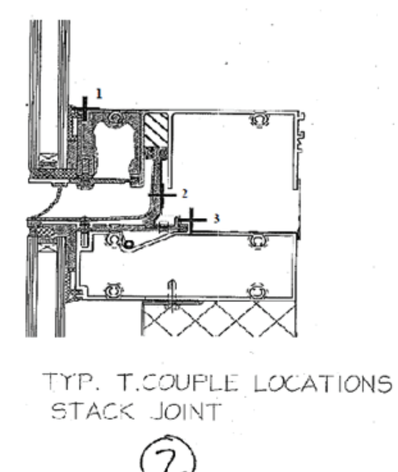
Figure 3. NFRC Procedure 102 U-Value.

IMPORTANCE OF WEATHER SEAL PERFORMANCE

A noteworthy result of testing was the determination that the performance of the outboard weather seal to resist air passage had a significant effect on the temperature of interior surfaces. Air flowing against the exterior of the system collects and is channeled into a "wall jet" that acts in the plane of the surface. Subsequently, both pressure and velocity vary with location and the channel (indicated in blue) formed behind the outer gasket allows for air movement between these zones. This effect was first realized in testing of the EPDM gasket and later studied by computational fluid dynamics CFD analysis. It was further determined that water drainage slots traditionally cut in the standard system also degraded performance. Additional tests of the baseline configuration were conducted with no gasket, the standard gasket, a double gasket and in a fully taped configuration. The temperature measured at the interior exposed surface of the chicken head rose with increasing levels of isolation







Test Configuration: Exterior Gasket in place - Interior of Stack Open

Thermocouple ID:	1	2	3
Average Temperature:	36.59	26.74	32.31

Test Configuration: Exterior Gasket in Place - Interior of Stack Taped

Thermocouple ID:	1	2	3
Average Temperature:	33.17	23.64	26.69

Test Configuration: Exterior Taped - Interior of Stack Open

Thermocouple ID:	1	2	3
Average Temperature:	44.16	38.58	40.27

Test Configuration: Exterior Gasket Removed - Interior of Stack Open

Thermocouple ID:	1	2	3
Average Temperature:	33.67	23.04	31.32

Figure 4. Typical stack joint details.

