Interlaboratory Comparison of Temperature Results for the Warm Surface of Window Assemblies Subjected to Winter Conditions

A Project Description for ASHRAE TC 4.5
Subcommittees on Condensation Resistance and Joint US/Canada Research

Revised February 9, 2000

Prepared by:

Brent Griffith
Lawrence Berkeley National Laboratory
BLDG. 53 Room 101
Berkeley, CA 94720
Tel. 510-486-6061
Fax 510-486-6046
BTGriffith@lbl.gov

INTRODUCTION

This proposal summarizes a joint research project that will compare results for surface temperatures on the same set of fenestration specimens at ASHRAE winter design conditions. Results are to be generated blindly by different research groups conducting both experiments and computer simulations. Experiments will subject specimens to winter conditions typical of a Hot Box and map surface temperatures on the warm side with non-contact infrared radiometers. Two dimensional simulations will model the experimental situation with both routine techniques for rating and more sophisticated research-level computations that analyze conduction, convection, and radiation heat transfer. This project is related to an earlier research project that studied seven different flat-mounted IGUs. This project differs in that it will study entire window products.

PARTICIPANTS

In addition to the participation listed in Table 1, the project is to remain open to other researchers who would like to contribute results. Information sufficient for creating simulation input data is posted on a web site (http://windows.lbl.gov/cr).

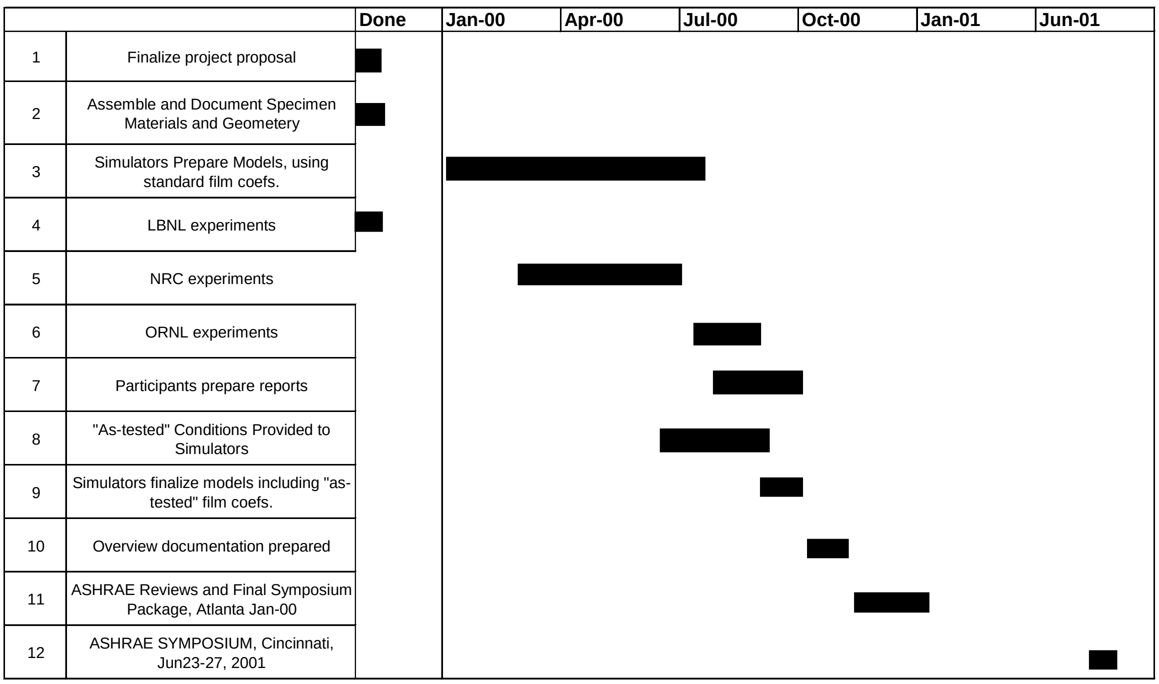
Table 1—Participants, Type of Contribution, and Contact Person

Research Institution	Contribution	Contact
LBNL	Infrared Measurements	Brent Griffith
LBNL	THERM Simulations	Christian Kohler
Univ. of Massachusetts	FIDAP and THERM Simulations	Dragan Curcija
NRC	Infrared and U-Factor Measurements	Hakim Elmahdy
ORNL	Infrared and U-Factor Measurements	Andre Desjarlais
Univ. of Waterloo	Bravo Simulations	Roydon Fraser
Univ. of Waterloo	FRAME/Vision Simulations	John Wright
WESTLab & LBNL	Overview	Jeff Baker Brent T Griffith

SCHEDULE

The current schedule is shown in Table 2. This schedule included changes made at the Dallas subcommittee meeting and targets completing the research and papers in time for the presentation at the ASHRAE meeting in Cincinnati to be held in June, 2001.

Table 2—Research Steps and Schedule



Schedule Discussion

1) Finalize Project Proposal.

   Finished: June 1999

   Participating researchers agree on the overall plan, specimen list, and basic procedures so that the work can be performed. This current plan is outlined in this document. If changes are needed, please forward information to Brent Griffith so that this document and the project web site can be updated.

2) Assemble and Document Information for Simulators

   Finished: Feb. 3, 2000

   Geometry and material property information have been collected and made available to simulators on a central, project specific web site, http://windows.lbl.gov/cr

3) Develop Specimen Models using Standard Film Coefficients
Start: Feb 2000
Finish: July 2000

Simulation researchers prepare models. Initial runs are conducted using standard surface heat transfer coefficients/conditions with the understanding that experimental conditions will differ and the models will need to be run again with "as-tested" conditions when those values become available later in the project.

4) LBNL Experiments

Finished: Nov 1999

LBNL perform infrared measurements on the three primary specimens using both imaging and point infrared detectors. Air conditions within 4 mm from the specimen's glazing surface were also measured. Measurements were performed at both ASHRAE and ISO temperature conditions. A reusable shipping crate was built to transport the specimens to the other laboratories.

5) NRC Experiments

Start: Feb 2000
Finish: July 2000

NRC will perform measurements on the three primary specimens. Data collected will include surface temperatures from non-contact infrared radiometer and U-factor.

6) ORNL Experiments
Start: July 2000
Finish: Sept 2000

ORNL will perform measurements on the three primary specimens. Data collected will include surface temperatures from non-contact infrared radiometer and U-factor.

7) Write papers
Start: July 2000
Finish: September 29, 2000

Participants prepare documentation to submit drafts by September 29, 2000 in order to complete reviews and overview paper by winter ASHRAE meeting in Atlanta, January 2001.

8) Provide "As-Tested" experimental conditions to simulators
Start: March 2000

Finish: September 2000

To the extent possible, experimental participants will provide ancillary data on the conditions found during the tests to simulation participants. “As tested” data on mean and/or local film coefficients are particularly important. This will most likely consist of results from CTS experiments. Glazing deflections or other changes in geometry may also be reported. For conjugate CFD simulations, air flows and radiation conditions at model boundaries may also be desirable. Surface temperature and U-factor results are not to be disclosed.

9) Finalize simulations with “as-tested” experimental conditions.
Start: August 2000
Finish: September 2000

Simulations should use boundary conditions that closely approximate what was experienced by the individual specimens at the individual laboratories in order for results to be comparable.

10) Write Overview Paper
Start: October 2000
Finish: November 2000

Results will be compiled from all participants into a summary paper that presents an overview, comparison, and discussion of the results.

11) ASHRAE reviews
Start: October 2000
Finish: January, 2001

Symposium Chair organizes reviews. Chair cannot be an author.

12) ASHRAE Symposium, Cincinnati June 2001.

Present results at ASHRAE Meeting

SPECIMENS

The main focus of the interlaboratory project will be to study the three specimens shown in Table 3. The primary set of specimens will be circulated between all test facilities and ultimately returned to LBNL. Drawings of the specimens are available as computer files on the project web site (http://windows.lbl.gov/cr/) and are included as Figures x thru y

Table 3—Primary Specimens

Specimen Number	Manufacturer (Model/type)	Type	Frame Material	Glazing Configuration	Overall Size
1	LBNL CTS	Foam Core Heat Flux Transducer	N/A	Foam Core ≈12.5 mm EPS	2' 0" x 3' 0"
2	Marvin 3-step	Fixed Casement	Wood	Dual, air-filled Clear-Clear 16.5 mm gap	2' 0" x 3' 0"
3	Marvin 3-step	Fixed Casement	Wood	Dual, air-filled Clear-Low-e 16.5 mm gap	2' 0" x 3' 0"

Testing

The specimens will be tested in laboratory hot-box chambers according to ASTM C-1199 (Revision 6) wherever this standard is applicable. If possible, two sets of tests could be completed at different temperature settings, -17.8° and 21.1°C as well as 0° and 20°C. (LBNL has completed measurements at both settings.) The foam core of the surround panel should have a nominal thickness of 150 mm. Specimen #1, the Calibrated Transfer Standard, will be mounted 25 mm in from the surround panel weather side surface. Specimen #1 should be tested first in order to verify (or adjust so) that the mean surface heat transfer rates are within 5% of 7.7 W/m^2-K on the warm side and 29 W/m^2-K on the cold side. Specimens # 2 and # 3 will be mounted in the surround panel with their weather side surfaces flush with the weather side surface of the surround panel. Perimeter joints between the test specimen and the surround panel will be sealed with tape on both sides of the test specimen.

A separate document has been prepared as a draft ASTM test method that provides guidance on performing the surface temperature measurements using infrared thermography.

SIMULATIONS

Simulations will model heat transfer through the window assemblies and related fluid movements. This is a research project and not a routine effort to simulate window U-factors. The final results will include U-factor, but of more interest is obtaining results for the surface temperature along the warm side surface. The surface temperatures are what determine the performance with regards to moisture condensation. Two-dimensional models will simulate the performance of the entire vertical cross section of a specimen and not just the edge of glass. The geometry for each two dimensional model is that of the vertical cross section along the centerline of the specimen. The surround panel should be included in the model for a distance of 75 mm above and below the specimen opening.

Boundary Conditions

One goal of this project is to investigate the effect that environmental boundary conditions have on the accuracy of computer simulations that attempt to predict the condensation resistance of a window product. Boundary conditions are comprised of free stream air temperatures and surface heat transfer rates. The main focus of the project is to use AHSRAE winter design conditions where free stream temperature conditions are 21.11°C on the warm side and 17.78°C on the cold side. Secondary results are desired for ISO conditions of 20.0°C on the warm side and 0.0°C on the cold side.

Simulations are also to be conducted with a variety of surface heat transfer rates or film coefficients. Some models will use only the total film coefficient that includes both radiative and convective heat transfer rates. Models that directly calculate radiation exchange will need the convective portion of the total film coefficient. It has been suggested to use three different sources for mean overall surface heat transfer coefficients, (1) NFRC/W4.1, (2) SPC142a/ISO 15099, and (3) measured values from CTS experiments. It is also possible to use *localized* convection surface heat transfer coefficients rather than mean values. (1) results from simulations at UMass and (2) measurements using traverse data from LBNL.) Thus, for each specimen, several sets of simulation results will be obtained corresponding to different film coefficient boundary conditions. Note that an iterative approach is necessary in some cases because some modeling boundary conditions depend on the surface temperatures, which are not known.

NFRC/W4.1 Fixed Boundary Conditions

NFRC has defined fixed boundary conditions for use in simulating frame sections and relies on the algorithms in Window 4.1 for the glazings. Table 1 lists final values for coefficients that should be used for the various regions of the three specimens. These values were determined from low-level operation of the W4.1 program (puke files) in order to provide this project a set of fixed boundary conditions. This will allow initial modeling efforts to proceed directly without having to iterate with boundary conditions that vary with surface temperature. (Window 4.1 has already performed temperature iterations to come up with the values for the glazing regions.) NFRC has fixed values for the total coefficient on the frame. Assuming a surface temperature of 12°C and calculating radiation using equation 10, allows separating out the convective and radiative parts of the warm side film coefficient. For the cold side, the correlation used by Window 4.1 for forced convection was used to determine the convective portion. (The "?s" in Table 1 reflect the fact that it would be useful to know the exact methodology used by NFRC to arrive at their fixed values.)

ISO 15099/SPC142A Temperature Dependent Boundary Conditions

These draft standards both provide essentially the same methods for determining surface film coefficients (and they differ from NFRC/W4.1) except for the cold side convective coefficient. The surface heat transfer coefficients are determined through the use of temperature dependent equations that are available elsewhere.

Table 1 Boundary Conditions: NFRC/W4.1Surface Heat Transfer Coefficients

Specimen	Region	Boundary Condition: Mean Coef.	Warm/Indoor Side (W/m·K)	Cold/Outdoor Side (W/m·K)
1	Glazing	Convective	3.10	25.46
CTS		Radiative	4.60	3.21
		Total	7.70	28.66
2	Glazing	Convective	3.40	25.46
Clear		Radiative	4.51	3.23
window		Total	7.91	28.69
3	Glazing	Convective	3.07	25.46
Low-E		Radiative	4.62	3.21
window		Total	7.69	28.67
1, 2, &3	Frame &	Convective	?2.92	?25.46
	Surround	Radiative	?4.69	?3.57
	Panel	Total	7.61	29.03

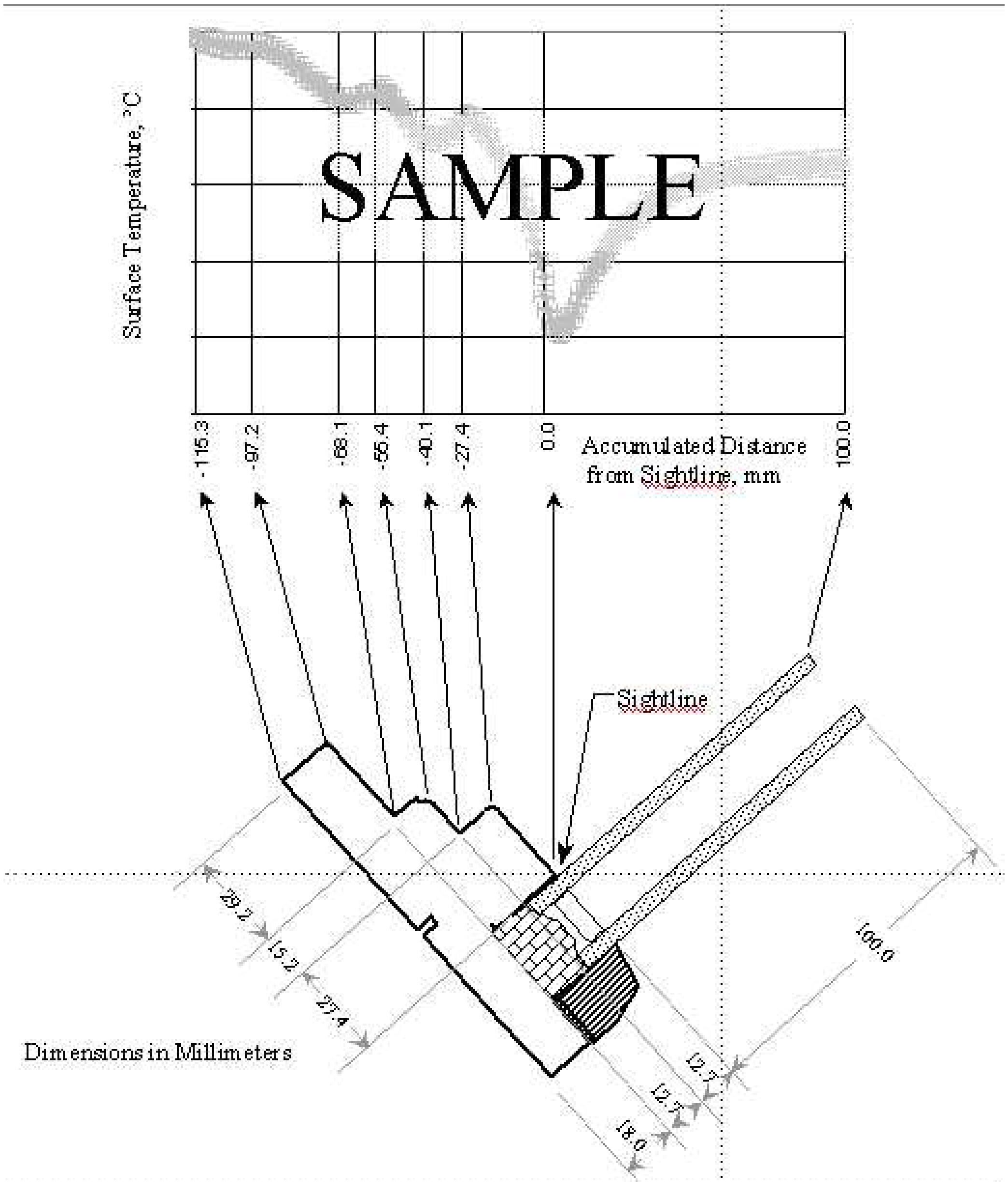
Material Properties

Table 2 Thermal Properties of Materials in Specimens 1, 2 and 3

Material	Thermal Conductivity W/m-K	Emissivity
Glass	1.0	0.84
Low-E Coating (Spec. 3)	N/A	0.10
Wood	0.14	0.90
Butyl Rubber	0.24	0.90
Steel ANSI 30 Stainless	14.3	0.2
PVC flexible	0.12	0.9
EPS foam, CTS core	0.034	0.9
EPS foam, Surround panel	0.036	0.9
Silica gel desiccant	0.03	0.9

DATA PRESENTATION

Measuring and modeling efforts need to arrive at data sets that allow for relatively simple comparison of results. Each set of temperature results should be presented in two different coordinate systems with the origin of both systems placed at the sill sightline of the window assembly or the bottom edge of the CTS. The first system will present data with the form *(x, y, T)*, where **x** is a spatial coordinate directed in the plane of the glazing, **y** is a spatial coordinate directed away from the plane of the glazing, and **T** is surface temperature. The second system would present data with the form *(l, T)* where **l** is the accumulated path length (from the origin) along the warm side surface of the profile. Data should be provided for 75 mm of the surround panel above and below the specimen, as well as the entire centerline section of the specimen. In order to help ensure that comparable coordinate systems are used, The description of specimen geometry for simulators will provide x and y locations of profile vertices and the associated values for path length. Small fillets and rounds will be neglected when determining accumulated distances along a frame profile.



SAMPLE
Surface Temperature, °C
-115.3
-97.2
-68.1
-55.4
-40.1
-27.4
0.0
100.0
Accumulated Distance from Sightline, mm
Sightline
29.2
15.2
27.4
100.0
12.7
12.7
18.0
Dimensions in Millimeters