SFPE STANDARDS-MAKING COMMITTEE ON CALCULATING FIRE EXPOSURES

Local Fire Exposures Working Group

Meeting Report – August 9, 2017

Present: Ulf Wickström (Working Group Leader), Jonathan Barnett, Sean Hunt, Brian Lattimer, Craig Beyler (Committee Chair) and Chris Jelenewicz (Staff).

The following was discussed:

- **Sub-Task 1 – Expressing boundary conditions**

After the last meeting, the Working Group unanimously approved a Ballot that listed 10 statements that are intended to develop a common vocabulary and set of definitions on how boundary conditions will be expressed in the standard. The final 10 statements are listed in the Annex of this report.

Moving forward it was agreed that the 10 statements will be used to guide the work of the committee and it may be placed in an Appendix of the revised standard.

Ulf distributed a draft White Paper that discusses how to express thermal exposure in the standard. Working group members were asked to review this paper before the next meeting. This paper is attached to this report.

- **Sub-Task 2 – Local exposure fires – available formulas.**

The Working Group was asked to look at a probabilistic approach for estimating local exposure fires. One paper was discussed at the Working Group meeting that was held on April 11. This report is posted on the SharePoint site.

Brian and Sean will discuss on how the working group can implement this probabilistic approach and report back at the next meeting.

- **Sub-Task 3 – Façade fires – available formulas**

Jonathan discussed a paper (Vertical safe separation distance between openings in multi-story buildings having a fire resistant spandrel) by Delichatsios, et al. This report is posted on the ShareDrive. It is possible that the methodology outlined in this report can be used as a bases for estimating façade fires that can be translated to useful information for a structural analysis. Jonathan will start the process of comparing this method to test data.

Sean will track down References 1 through 6 in the Delichatsios report. He will also look at the existing dataset to see if there is any test data related to external burning. Ulf pointed out that it is important that the exposure levels obtained from any fire model must be expressed in such a way that they can be used as input to models for calculating temperature in exposed structures. One way is to express the exposure levels in terms of adiabatic surface temperature. See the 'ten statements'.

- **General Discussion**

  A paper that was presented at the IAFSS meeting in June 2017 by Maluk on fire testing was briefly discussed. Jonathan volunteered to discuss this report with the authors.

- **Next meeting** – The next working group meeting will be held in late September. CJ will schedule via a Doodle Poll.

End of Report

Annex

Common Vocabulary and Definitions for Boundary Conditions

Approved by the SFPE Standard S.01 Local Fire Exposures Working Group
by Ballot on August 9, 2017

1. Thermal exposure is governed by two independent parameters, *incident radiant heat flux* (or irradiance) $\dot{q}''_{inc}$ and *gas temperature* T_g. [1]
2. Heat is transferred to solid surfaces by radiation and convection, here denoted $\dot{q}''_{tot} = \dot{q}''_{rad} + \dot{q}''_{con}$ where the net radiation is the difference between the absorbed and emitted radiation, i.e. $\dot{q}''_{rad} = \dot{q}''_{abs} - \dot{q}''_{emi}$. [2]
3. The incident radiation can alternatively be expressed as $\dot{q}''_{inc} \equiv \sigma \cdot T_r^4$. The radiation temperature $T_r \equiv \sqrt[4]{\frac{\dot{q}''_{inc}}{\sigma}}$ may be either greater or smaller than the gas temperature T_g.
4. The heat transfer $\dot{q}''_{tot}$ to solid surfaces consists of three independent components, absorbed heat by radiation $\dot{q}''_{abs} = \alpha_s \cdot \dot{q}''_{inc}$, emitted heat by radiation $\dot{q}''_{emi} = \varepsilon_s \cdot \sigma \cdot T_s^4$ and heat transferred by convection $\dot{q}''_{con} = h\left(T_g - T_s\right)$, i.e. $\dot{q}''_{tot} = \varepsilon_s \cdot \dot{q}''_{inc} - \varepsilon_s \cdot \sigma \cdot T_s^4 + h\left(T_g - T_s\right)$. [3]
5. Gas temperature T_g can be measured with very thin or aspirating thermocouples. Incident radiation $\dot{q}''_{inc}$ or T_r can be measured using radiometers.
6. Heat flux (radiation plus convection) is often measured in Fire Safety Engineering (FSE) with water-cooled Heat Flux Meters (HFM). Given an exposed surface is assumed to have the same emissivity and convection heat transfer coefficient as the HFM sensor, the heat transfer to an exposed surface can be calculated as $\dot{q}''_{tot} = \dot{q}''_{HFM} - \varepsilon_s \cdot \sigma(T_s^4 - T_{HFM}^4) - h(T_s - T_{HFM})$ where T_{HFM} is the temperature of the sensor surface.
7. With a given relation between ε_s and h a single 'effective' exposure temperature, the *adiabatic surface temperature* T_{AST}, can be defined by the relation $\varepsilon_s \cdot \sigma(T_r^4 - T_{AST}^4) + h\left(T_g - T_{AST}\right) = 0$ or $\varepsilon_s(\dot{q}''_{inc} - \sigma \cdot T_{AST}^4) + h\left(T_g - T_{AST}\right) = 0$. T_{AST} is always between T_g and T_r.
8. The heat flux to a surface with a temperature T_s can then be calculated as $\dot{q}''_{tot} = \varepsilon_s \cdot \sigma(T_{AST}^4 - T_s^4) + h(T_{AST} - T_s)$.
9. T_{AST} can be measured with Plate Thermometers. PTs shall have large surfaces to get a convection heat transfer and an emissivity close to a real exposed body. The PT sensing plate is thin to achieve a fast time response (a short time constant). As incident radiation depends on directions, the PT temperature T_{PT} and T_{AST} depend on orientation.
10. Given the HFM and PT are assumed to have the same emissivities and convection heat transfer coefficients, $\dot{q}''_{HFM} = \varepsilon_s \cdot \sigma(T_{AST}^4 - T_{HFM}^4) + h(T_{AST} - T_{HFM})$

[1] As these *two* parameters are independent they cannot generally be replaced by *one* single parameter like for instance 'fire temperature' or 'heat flux'.

[2] $\dot{q}''_{tot}$ is often denoted $\dot{q}''_{net}$ in FSE literature.

[3] The heat transfer from the gas phase to a solid surface in a fire cannot be expressed as a given constant or varying with time heat flux boundary condition since the surface temperature changes depending on the response of the solid.