SFPE STANDARDS-MAKING COMMITTEE ON CALCULATING FIRE EXPOSURES

Local Fire Exposures Working Group

Meeting Report – March 7, 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 -** continuing discussions on definitions and measurements.

A. The working group reviewed a series of statements that Ulf presented at the last working group meeting. These statements are intended to develop a common vocabulary and set of definitions on how boundary conditions will be expressed in the standard. Based on these discussions, the working group agreed on the following statements:

1) Thermal exposure is governed by two independent parameters, incident radiant heat flux $\dot{q}''_{inc}$ and gas temperature T_g. As they are independent they cannot generally be replaced by one single parameter like just 'fire temperature' or 'heat flux."

2) Heat is transferred to solid surfaces by radiation and convection, here denoted $\dot{q}''_{tot} = \dot{q}''_{rad} + \dot{q}''_{con}$. $\dot{q}''_{rad}$ is in general textbooks on heat transfer often called net radiant heat, $\dot{q}''_{net}$. In FSE literature, however, $\dot{q}''_{tot}$ is in often named $\dot{q}''_{net}$ which is an unfortunate denomination as the convection term cannot be split into positive and negative physical components.

3) The incident radiation can alternatively be expressed as $\dot{q}''_{inc} \equiv \sigma \cdot T_r^4$ or $T_r \equiv \sqrt[4]{\frac{\dot{q}''_{inc}}{\sigma}}$. The radiation temperature T_r may be either greater or smaller than the gas temperature T_g.

4) T_g can be measured with thin thermocouples. $\dot{q}''_{inc}$ or T_r can be measured in room temperature but in practice not in flames or hot gases. It was agreed that this statement will be expanded to say -- convective and radiation heat transfer measurements are difficult to make.

5) The heat transfer to a solid surface 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 convection $\dot{q}''_{con} = h(T_g - T_s)$. These three components depend on the radiation temperature T_r (or incident radiation $\dot{q}''_{inc}$), the surface temperature T_s and the difference between the gas temperature and surface temperature $(T_g - T_s)$, respectively.

6) Depending on the relation between ε_s and h a single exposure temperature can be defined named the adiabatic surface temperature T_{AST}. This temperature is always between T_g and T_r.

7) The heat flux to a surface with a temperature T_s can then be calculated as $\dot{q}''_{tot} = \varepsilon_s \cdot \sigma \cdot (T_{AST}^4 - T_s^4) + h(T_{AST} - T_s)$.

8) T_{AST} can be measured with plate thermometers, approximatively but in most cases accurately enough. PTs have large surfaces to get a convection heat transfer coefficient/emissivity relation as close to a real exposed body as practically possible. If the PT is thin it will respond faster. Radiation is directional.

9) The boundary condition (BC) of a fire exposed body is a third kind of BC. That is, it depends on surrounding temperatures (gas and radiation), the surface temperature and heat transfer conditions, surface emissivity and convection heat transfer conditions. In its simplest form a third kind of BC can be written as $\dot{q}'' = h(T_g - T_s)$.

10) The boundary condition of a fire exposed body cannot be expressed as second kind of BC, i.e. a given heat flux, as the heat to a surface will always depend on the thermal response of the surface, i.e. the surface temperature.

11) When a boundary condition is expressed as 'heat flux' it is generally meant to be interpreted as the heat flux to a surface at ambient temperature. Such a BC can be reformulated to a BC of the third kind which is specifically needed when used as input to general temperature calculation codes like ABAQUS or Tasef.

There was also a discussion on an additional statement (12). At this time the working group did not agree but will discuss further at the next meeting.

12) Heat flux measured in flames or hot gases with water-cooled heat flux meters are difficult to interpret as boundary conditions for calculation of solid phase temperatures. The heat transfer by convection to the water-cooled and small sensor is then very high and very uncertain. It is therefore not possible to estimate the thermal exposure of real body surfaces based on measurements with water-cooled heat flux meters in flames and hot gases.

B. **Ulf's memo from 2017-02-25, how to express thermal exposure** – The memo was briefly reviewed and will be discussed further at the next meeting. Specifically, the following question was raised: if a boundary condition in a standard is given as a 'heat flux' should it first be translated into adiabatic surface temperature. To do this a 'nominal' $\hat{\boldsymbol{\varepsilon}}$ and $\hat{h}$ may need to be specified in the standard to assure that the exposure will always be the same independent of exposed body. But it was noted that the h and ε_s according to the equation under item 7 above will depend on the actual exposed surface and will therefore not generally be the same value as when specifying the adiabatic temperature. It was agreed that this issue will be discussed at the next meeting.

   Working group members were asked to look for test reports that collect test data where plate thermometers and conventional thermocouples are used in same test. Brian indicated he has reports that he will send to the working group.

C. **New Paper from Brian** – Brian forwarded a draft paper "Comparison of Heat Flux and Adiabatic Surface Temperature Boundary Conditions" that discusses how to predict thermal boundary conditions from a fire to a surface using a model such as FDS and transferring this data as an input to temperature calculation models such as Abaqus and Tasef. This paper will be discussed at the next meeting.

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

  Sean has uploaded several documents to the ShareDrive. He will provide a short write-up on these documents and report back at the next meeting.

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

  Jonathan indicated that most of the info used in the Eurocode is based on the work of Margaret Law. Besides that, there is not much data available. At the next meeting the working group will discuss a path forward.

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

End of Report