SFPE STANDARDS-MAKING COMMITTEE ON CALCULATING FIRE EXPOSURES

Local Fire Exposures Working Group

Meeting Report – January 31, 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:

A. **Expressing boundary conditions (Sub Task 1) –** There was a broad discussion on how boundary conditions will be expressed in the standard. A paper submitted by Ulf was reviewed. The purpose of this paper was to develop a common vocabulary and set of definitions.

   The working group also review the SFPE Handbook Chapter on 'Heat transfer form fires to surfaces' by Lattimer, pp. 745-749. It was noted that the two documents are not in conflict. However, the way of expressing and using data are different which make it more or less easy to use and understand. Specifically, the working group discussed 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. In fire resistance of structures analyses they are usually assumed equal, a uniform fire or furnace temperature T_f.

   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.

   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. It is thin to get a fast response. Radiation is directional.

9) The boundary condition 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.

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.

It was noted that a lot of data is obtained from fire tests that used water cooled heat flux gauges. So it is important to include heat flux gauges in our discussion.

There is a lot of uncertainty when defining the convection coefficient (h) in a calculation, even if adiabatic surface temperature is used in the calculation.

Most research does not focus on heat transfer by convection in these sorts of experiments.

If you don't know the exact convective heat transfer coefficient when you do the actual calculation, but one is selected, both methods (water cooled heat flux gauge vs plate thermometer) should give you the same answer. Ulf argued, however, that the problem of uncertainty is much smaller when using PTs. Brian promised to take closer look at the 12 statements before the next meeting.

For this standard, it was agreed that we want to give users the best guidance on how to draw the best conclusions and understand the uncertainties no matter what method is used.

The working group needed more time to review Items 1 through 12.These items will be discussed at the next meeting.

Also, before the next meeting ULF will circulate a paper that was submitted to Interflam and Brian will circulate some information related to FDS.

B. Local fires (Sub Task 2) -- At the next working group meeting, Sean will discuss looking at available data and calculation models, including the models in the existing standard and the methodology used in the Eurocode.

C. Façade fires (Sub Task 3) – At the next working group meeting, Jonathan will discuss if any data and methods are available for estimating façade fires.

D. Next meeting – The next working group meeting will be held in March. CJ will schedule the next meeting via a Doodle Poll.

End of Report