The IAFSS Working Group on Measurement and Computation of Fire Phenomena (*MaCFP*)

First MaCFP Workshop, Lund University – June 10-11, 2017

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FIRE SAFETY SCIENCE

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- **The MaCFP Working Group**
  - A new initiative endorsed by the International Association for Fire Safety Science (IAFSS, http://www.iafss.org)

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Motivation

- Fire modeling features several technical challenges
  - Relatively slow, buoyancy-driven flow; Flame extinction/ignition; Complex solid fuel sources (pyrolysis); Soot formation; Radiation-turbulence interactions
  - Progress is needed to simulate: **flame spread, water-based suppression, smoke toxicity**, *etc*
- Community faces an organizational challenge
  - Fire modeling community (modelers and experimentalists) is small, fragmented, geographically dispersed, without a history of well-defined standards and without a consensus on well-defined objectives
  - There is a need for a coordinated effort to organize and strengthen the fire modeling community

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- **General objective**
  - A joint effort between experimentalists and modelers to develop a fundamental understanding of fire phenomena and to establish a common framework for fire modeling research

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- **Format**
  - A regular series of workshops, with a first workshop organized as a pre-event to the 12th IAFSS Symposium in Lund (June 2017) and subsequent workshops held every two years

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- **Brief history**
  - Pre-Symposium workshop "*Benchmarking/Data Sharing*" at the 11th IAFSS Symposium in Christchurch (February 2014)
  - Task group
    - A. Brown, S. Dorofeev, G. Jomaas, R. McDermott, B. Merci (*co-Chair*), V. Raman, A. Simeoni, J. Torero, A. Trouvé (*co-Chair*), P. van Hees, Y. Wang
    - White paper
    - Endorsement of IAFSS (March 2015)

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- **Brief history**
  - Planning meeting (May 2015) and plans for first workshop
    - List of target experiments for first MaCFP Workshop (June 2017)
    - Organizing Committee: A. Brown, M. Gollner, J. Hewson, A. Marshall, R. McDermott, B. Merci (*co-Chair*), J. Torero (*co-Chair*), A. Trouvé (*co-Chair*), Y. Wang, E. Weckman
    - Website: http://www.iafss.org/macfp/
  - Call for participation
    - *Fire Safety J.* **82** (2016) 146-147
    - *Fire Technology* **52** (2016) 607-610
    - Email to IAFSS membership

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- **Brief history**
  - New condensed phase effort and formation of 2 subgroups: the *Gas Phase Phenomena* subgroup and the *Condensed Phase Phenomena* subgroup (Summer 2016)
    - Organizing Committee of the *Condensed Phase Phenomena* subgroup: M. Bruns, T. Rogaume, S. Stoliarov
    - Planning meeting (June 11 2017)

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- **Specific objectives/deliverables**
  - Develop a digital archive of well-documented target fire experiments that can be used for CFD model validation
  - Develop a digital archive of corresponding well-documented CFD-based numerical simulations
  - Develop protocols for detailed comparisons between computational results and experimental measurements
  - Identify key research topics and knowledge gaps in computational and experimental fire research
  - Develop best practices in both computational and experimental fire research (*e.g.*, quality control, UQ)
  - Establish a network between fire researchers and provide a community-wide forum for discussion

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List of target experiments

- ✓ Basic configurations (building blocks) with carefully-controlled conditions and quality instrumentation; and with available databases
- ✓ **Building block approach** to CFD validation: a physics-based approach that considers a series of configurations representing different aspects of fire phenomena with increasing complexity (flow, mixing, fuel sources, combustion, soot formation, thermal radiation, system effects)

  - Turbulent mixing (no combustion)
  - Turbulent flame with controlled fuel flow rate (gaseous fuel)
  - Turbulent flame with uncontrolled fuel flow rate (liquid fuel)
  - Turbulent flame with uncontrolled fuel flow rate (solid fuel)
  - *etc*

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- **List of target experiments**
  - ✓ Basic configurations (building blocks) with carefully-controlled conditions and quality instrumentation; and with available databases
  - ✓ Initial choices: simple flames (in most cases, with no/little soot); with gaseous/liquid fuel (no solid fuel); and with open burn conditions (no compartment effect)

- *Category* 1: Turbulent buoyant plumes
- *Category* 2: Turbulent pool fires with gaseous fuel
- *Category* 3: Turbulent pool fires with liquid fuel
- *Category* 4: Turbulent wall fires
- *Category* 5: Flame extinction

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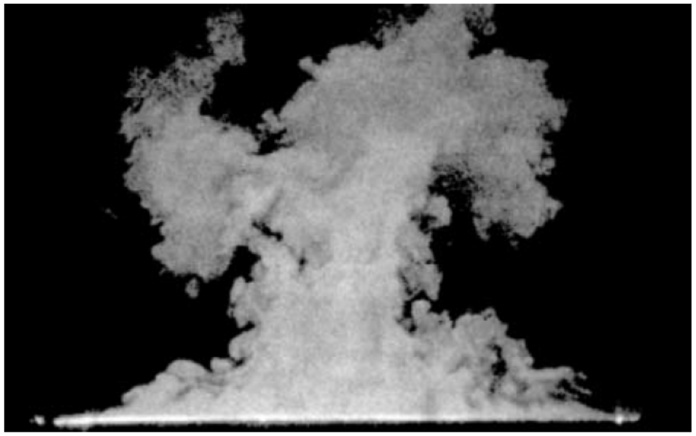

- **List of target experiments**
  - *Category* 1: Turbulent buoyant plumes
    - **Sandia Helium Plume** (O'Hern, Weckman, Gerhart, Tieszen, Schefer, *J. Fluid Mech*., 544 (2005) 143-171)
      - *Configuration*: large-scale (1-m diameter) helium plume
      - *Features*: Rayleigh-Taylor instabilities at both large-scales (puffing motion) and small-scales (bubble and spike structures)
      - *Data*: measurements of flow velocity (PIV) and helium mass fraction (PLIF) with both first- and second-order statistical moments

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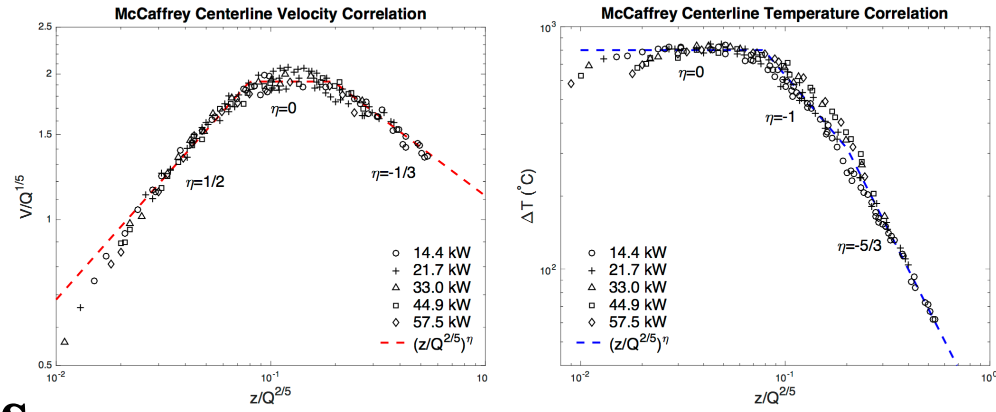

List of target experiments

- *Category* 2: Turbulent pool fires with gaseous fuel (and prescribed fuel flow rate)
  - **NIST McCaffrey Natural Gas Flames** (McCaffrey, National Bureau of Standards, Report NBSIR 79-1910, (1979))
    - *Configuration*: small-scale (0.3-m square burner, 14.4-57.5 kW) natural-gas-air flame
    - *Data*: measurements of flow velocity (bi-directional probes) and temperature (thermocouples). Data are limited to centerline locations.

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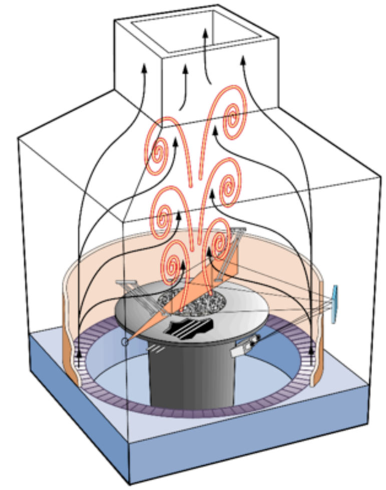

- **List of target experiments**
  - *Category* 2: Turbulent pool fires with gaseous fuel (and prescribed fuel flow rate)
    - **Sandia Methane and Hydrogen Flames** (Tieszen, O'Hern, Schefer, Weckman, Blanchat, *Combust. Flame*, 129 (2002) 378-391; Tieszen, O'Hern, Weckman, Schefer, *Combust. Flame*, 139 (2004) 126-141)
      - *Configuration*: large-scale (1-m diameter, 1.6-2.6 MW) methane- or hydrogen-air flame
      - *Features*: Rayleigh-Taylor instabilities at large-scales (puffing motion)
      - *Data*: measurements of flow velocity (PIV) with both first- and second-order statistical moments. Data are limited to the flame base region (below 1 m elevation).

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- **List of target experiments**
  - *Category* 3: Turbulent pool fires with liquid fuel (and thermal-feedback-driven fuel flow rate)
    - **Waterloo Methanol Pool Flame** (Weckman, Strong, *Combust. Flame*, 105 (1996) 245-266)
      - *Configuration*: small-scale (30-cm diameter, 24.6 kW) methanol-air flame
      - *Features*: Rayleigh-Taylor instabilities at large-scales (puffing motion)
      - *Data*: simultaneous measurements of flow velocity (LDV) and temperature (fine wire thermocouples) with first- and second-order statistical moments. Data are limited to the flame base region (below 0.3 m elevation).

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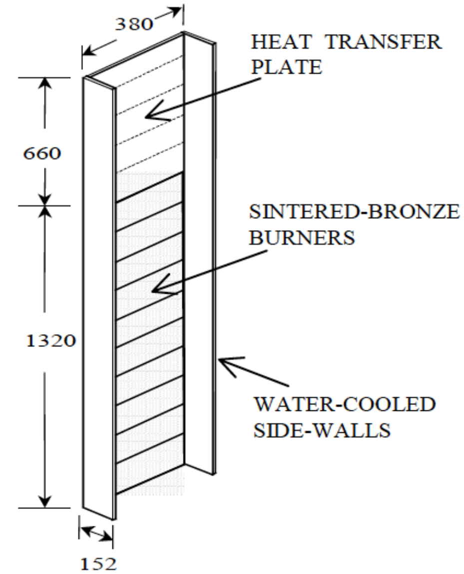
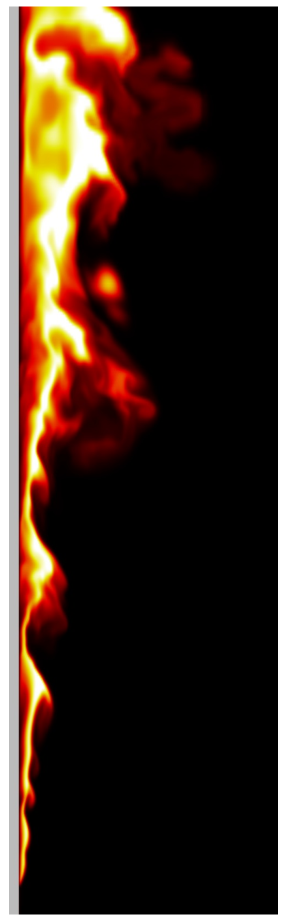


- **List of target experiments**
  - *Category* 4: Turbulent wall fires
    - **FM Global Vertical Wall Flames** (de Ris, Markstein, Orloff, Beaulieu, Factory Mutual Research Tech. Report J.I. 0D0J9.MT (1999); de Ris, Markstein, Orloff, Beaulieu, *Fire Safety Science – Proc. Seventh Intl. Symposium*, *IAFSS,* (2002) 259-270)
      - *Configuration*: medium-scale (meter-scale, 100s kW) turbulent vertical wall flames in configurations with a prescribed gaseous fuel flow rate; different fuels (methane, ethane, ethylene, propylene) and different fuel flow rates
      - *Data*: measurements of the total wall heat flux and temperature (thermocouples). For some cases, the experimental database also includes measurements of the flow velocity (LDV).



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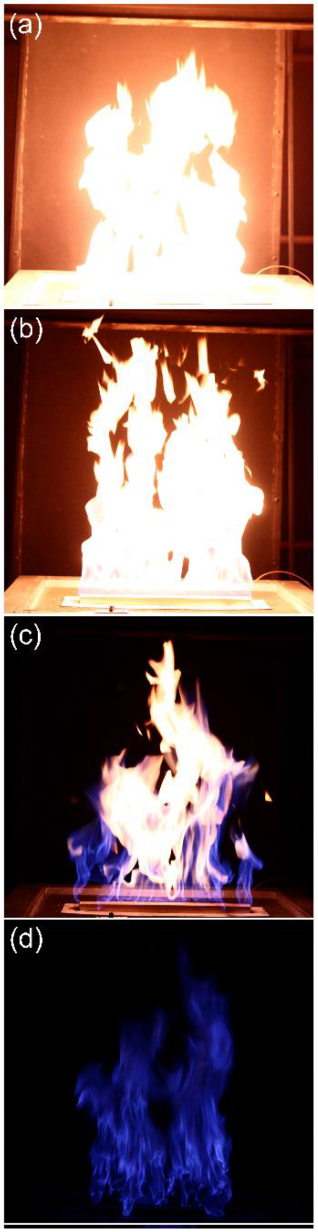
- **List of target experiments**
  - *Category* 5: Flame extinction
    - **UMD Methane and Propane Line Flames** (White, Link, Trouvé, Sunderland, Marshall, Sheffel, Corn, Colket, Chaos, Yu, *Fire Safety J.*, 76 (2015) 74-84)
      - *Configuration*: small-scale (50 kW) methane- or propane-air flames (Wolfhard-Parker slot burner); prescribed co-flow of variable oxygen strength (mixture of air and nitrogen)
      - *Features*: oxygen extinction limit
      - *Data*: measurements of the global radiative loss fraction (single-point heat flux sensor combined with a weighted multipoint radiation source model), the global combustion efficiency (O_2 and CO_2 calorimetry), temperature (micro-thermocouples)



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- **Repository**
  - Hosted on GitHub (https://github.com/MaCFP)
  - Descriptions of each selected target experiment
  - Electronic copies of experimental data organized in simple comma-delimited ASCII files
  - Protocols to perform comparisons between experimental data and simulation results through (provided) MATLAB-based post-processing tools
  - Electronic copies of computational results submitted by researchers, also organized in simple comma-delimited ASCII files

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- **Computational results**
  - Category 1: Sandia Helium Plume
    - G. Boyer (IRSN)
    - R. McDermott *et al.* (NIST)
    - G. Maragkos *et al.* (UGent)
  - Category 2: NIST McCaffrey Natural Gas Flames
    - G. Boyer (IRSN)
    - O. Oluwole *et al.* (FM Global)
    - R. McDermott *et al.* (NIST)
    - G. Maragkos *et al.* (UGent)

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- **Computational results**
  - Category 2: Flames Sandia Methane and Hydrogen Flames
    - R. McDermott *et al.* (NIST)
    - J. Hewson, H. Koo (SNL)
    - D. Alvear Portilla, M. Lázaro Urrutia, A. Alonso Ipiña (UCantabria)
    - G. Maragkos *et al.* (UGent)
  - Category 3: Waterloo Methanol Pool Flame
    - G. Maragkos *et al.* (UGent)
    - A. Marchand *et al.* (UMD)
    - T. Sikanen *et al.* (VTT)

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- **Computational results**
  - Category 4: FM Global Vertical Wall Flames
    - N. Ren *et al.* (FM Global)
    - K. McGrattan *et al.* (NIST)
  - Category 5: UMD Methane and Propane Line Flames
    - N. Ren *et al.* (FM Global)
    - R. McDermott *et al.* (NIST)
    - A. Marchand *et al.* (UMD)

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- **Computational results**
  - Seven groups
    - FM Global (USA)
    - IRSN (France)
    - NIST/VTT (USA, Finland)
    - SNL (USA)
    - UCantabria (Spain)
    - UGent (Belgium)
    - UMD (USA)

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Computational results

- Four solvers
  - **Fire Dynamics Simulator** (FDS)
    - Developed by NIST (https://github.com/firemodels/fds)
    - *Version 6.5.3*
  - **FireFOAM**
    - Developed by FM Global (https://github.com/fireFoam-dev)
    - *Versions 1.6, 2.2.x, 2.4.x, dev*
  - **ISIS**
    - Developed by IRSN (https://gforge.irsn.fr/gf/project/isis/)
    - *Version 4.8.0*
  - **SIERRA/Fuego**
    - Developed by SNL
    - *Version 4.4.4*

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- **Computational results**
  - Different levels of maturity
    - From completed projects/published work to unpublished work-in-progress

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- **Comparison between experimental/computational data**
  - Open discussion with the objective to highlight strengths and weaknesses of CFD-based fire models in general
    - Caution: adopt a collegial tone, not a competition between solvers or development teams!
  - Format: sequentially review the list of 6 target experiments
    - 25-minutes presentation by two members of the Organizing Committee followed by 25-minutes open discussion
  - Proceedings
    - Intent to keep a record of discussions and to write and publish Proceedings of the Workshop (online on http://www.iafss.org/macfp/)