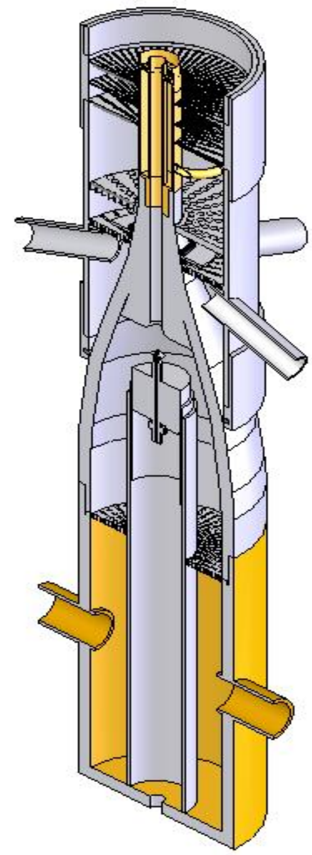
# Sydney's Burner for Turbulent Piloted Dilute Sprays

## Burner and data base:



The Sydney piloted burner shown here in isometric section, is adopted as a target platform for TCS calculations. The central jet nozzle diameter D is 10.5 mm, the outer diameter of the annulus is 25.0 mm and the lip thickness is 0.2 mm. The pilot flame holder is fixed 7.0 mm upstream of the nozzle exit. A co-flow of diameter 104 mm surrounds the burner and the co-flow/burner assembly is mounted in a vertical wind tunnel. The tunnel exit has a cross section of 290 x 290 mm. The exit plane of the co-flow and nozzle are located 59.0 mm downstream of the exit plane of the wind tunnel. Spray is generated using a Sono-Tek ultrasonic nebulizer (model number 8700-48) with its head located 215 mm upstream of the jet exit plane. Droplets of liquid fuel are generated on the nebulizer's surface, initially with zero momentum, and convected downstream to the burner's exit plane with a carrier stream of air (unless stated otherwise). Further details about the burner and the complete data set may be found in:


1. Gounder, J.D., Kourmatzis, A., Masri, A.R., 'Turbulent Piloted Dilute Spray Flames: Flow Fields and Droplet Dynamics', Combustion and Flame, 159:3372–3397 (2012).
2. Masri, A.R., and Gounder, J.D., 'Turbulent Spray Flames of Acetone and Ethanol Approaching Extinction', Combust. Sci. Technol. 182:702-715 (2010).
3. http://sydney.edu.au/engineering/aeromech/thermofluids/database.htm


A total of eleven test cases are selected for further calculations at the TCS Workshops and these are listed in Tables 1&2 with some relevant inflow conditions. Five cases are for non-reacting sprays (KS6, KS7, SP2, SP6 and SP7) while the six other reacting cases are for acetone (AcF2, AcF6, AcF7) and ethanol (EtF2, EtF6, EtF7) flames. Transitioning from Cases 2 to 6 involves additional spray loading at the same carrier velocity and from Cases 2 to 7 involves the same spray loading but higher carrier velocity.

**Note**: Cases KS6 and KS7 are new and now available online (see Table 2). These are non-reacting kerosene jets which may be used to validate dispersion models since evaporation is in these flows is almost negligible.

## Progress in recent TCS Workshops:

- In TCS3, (Heidelberg, 2012) preliminary calculations were presented for selected ethanol and acetone cases.

- In TCS4 (Cesme, Turkey 2013), some extensive comparisons were presented for the following sequence of cases:
  1. KS6 as non-reacting, non-evaporating
  2. SP2, SP6 and SP7 as non-reacting, evaporating and
  3. EtF2, EtF6 and EtF7 as reacting with ethanol as fuel.
  4. AcF2, AcF6 and AcF7 as reacting with acetone as fuel.

  Having a corresponding non-evaporating case (KS6) and non-reacting case (SP6) was useful as a tool to validate the dispersion and evaporation part of the models. Good results for SP6 only were generally obtained. Results for EtF6 results were all over the place – some good results but sufficient variability even within the LES approach. Temperature results were off for all flames regardless of the models used.

- The focus of TCS5 (Rhodes, 2015) was is to explore and understand the variability in the calculations with changes in the boundary conditions or in the models used. More specifically, answers were sought to the following questions:
  1. What are the effects of the spatial distribution of droplets, droplet size and velocity distributions at the exit of the pipe on the downstream structure of the spray jet and/or flame?
  2. What role does evaporation in the pipe play in the organization of the reaction zones near the inlet? Do non-equilibrium models change droplet size behavior? If so, what is the specific reason for this change?

  An extensive study of boundary conditions was presented. Results are summarized in a full presentation which is posted on the Workshop website

Table 1: Initial conditions for the non-reacting (SP2, SP6 and SP7) and reacting acetone (AcF2, AcF6, AcF7) and ethanol (EtF2, EtF6, EtF7) selected for the TCS Workshops.

| Spray Cases | **SP2** | **SP6** | **SP7** | **AcF2** | **AcF6** | **AcF7** | **EtF2** | **EtF6** | **EtF7** |
|---|---|---|---|---|---|---|---|---|---|
| Bulk Jet Velocity $U_{jet}$ (m/s) | 36 | **36** | **60** | 36 | **36** | **60** | 36 | 36 | 60 |
| Carrier | Air | Air | Air | Air | Air | Air | Air | Air | Air |
| Carrier mass flow rate (g/min) | 225 | 225 | 376 | 225 | 225 | 376 | 225 | 225 | 376 |
| Liquid fuel injection rate (g/min) | 75 | 45 | 75 | 75 | 45 | 75 | 75 | 45 | 75 |
| Measured liq. flow at exit (g/min) | 28.8 | 28.5 | 34.0 | 23.9 | 26.2 | 31.1 | 66.6 | 41.3 | 73.0 |
| Vapor fuel flow rate at jet exit (g/min) | 46.2 | 16.5 | 41.0 | 51.1 | 18.8 | 43.9 | 8.4 | 3.7 | 2.0 |
| Spray Jet Density (kg/m$^3$) | 1.44 | 1.38 | 1.36 | 1.44 | 1.38 | 1.36 | 1.56 | 1.42 | 1.43 |
| Spray Jet vapor phase Viscosity ($10^{-5}$)(kg/m-s) | 1.71 | 1.87 | 1.83 | 1.69 | 1.86 | 1.82 | 1.92 | 1.96 | 1.97 |
| Jet Reynolds Number | 31900 | 27900 | 46900 | 32100 | 28100 | 47100 | 30700 | 27400 | 45700 |
| Flame Length $L_f$ (cm) | | | | 53 | 48 | 48 | 72 | 53 | 68 |
| Overall equivalence ratio ($\Phi_{overall}$) | | | | 3.2 | 1.9 | 1.9 | 3.2 | 1.9 | 1.9 |
| Equivalence ratio at jet exit ($\Phi_{exit}$) | | | | 2.2 | 0.8 | 1.1 | 0.34 | 0.15 | 0.05 |

Table 2: Initial conditions for the non-reacting/non-evaporating cases (KS6 & KS7)

| Non- Reacting Spray Cases – Kerosene | **KS 6** | **KS 7** |
|---|---|---|
| Bulk Jet Velocity $U_{jet}$ (m/s) | 36 | 60 |
| Carrier | Air | Air |
| Carrier mass flow rate (g/min) | 225 | 376 |
| Liquid fuel injection rate (g/min) | 45 | 75 |
| Measured liq. flow at exit (g/min) | 37.7 | 66.1 |
| Vapor fuel flow rate at jet exit (g/min) | 0* | 0* |
| Spray Jet Density (kg/m$^3$) | 1.44 | 1.43 |
| Spray Jet Viscosity ($10^{-5}$) (kg/m-s) | 1.98 | 1.98 |
| Jet Reynolds Number | 27425 | 45447 |

*difference in measured and expected liquid mass flow-rate is strongly attributed to inherent inaccuracy of volume flux measurements, which can be of the order of 15% (see Gounder et al., Comb. Flame 159:3372–3397 (2012)).