

# Comparison of the Effect of Dimethoxymethane (DMM) or Diethoxymethane (DEM) Addition in a Rich Ethylene-Oxygen-Argon Flame on Soot Precursors Depletion

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## Abstract

Structures of three premixed ethylene-oxygen-argon rich flat flames ( $\phi = 2.50$ ) burning at 50 mbar have been established by using molecular beam mass spectrometry in order to investigate the effect of dimethoxymethane or diethoxymethane addition on species concentration profiles. Both additives cause a slight shift downstream of the flame and are responsible for a decrease of the maximum mole fractions of  $C_2$  to  $C_{10}$  intermediates which is more efficient in the case of DMM addition. The linear correlation of maximum mole fractions measured for most of  $C_2$  to  $C_{10}$  species with the initial C/O ratio of the corresponding flame indicates that soot precursors levels in rich flames are governed mainly by this parameter instead of the equivalence ratio when an oxygenated compound is added.

## Introduction

An important area of research in combustion is the identification and the understanding of the chemical effect of soot suppressors. However, little research works have been devoted to this topic in premixed flames. Among them, Haynes et al. [1] investigated premixed ethylene-air flames at atmospheric pressure to which up to 3 % of gaseous compounds were added and noticed that some additives ( $O_2$ , NO,  $NH_3$ ,  $H_2S$ ,  $SO_2$  and  $SO_3$ ) reduce significantly the soot volume fraction. Vandooren et al. [2] observed that in a moderate rich methane-oxygen-argon premixed flame with an equivalence ratio of 1.68 the addition of  $CO_2$  leads to a decrease of the  $C_2H_2$  and  $C_4H_2$  quantities in the burnt gases region. Moreover, Vandooren et al. [3-5] also demonstrated that in rich ethylene-oxygen-argon premixed flames with equivalence ratios of 2.25 and 2.50 the addition of  $CO_2$ , or  $NH_3$ , or  $H_2O$  is responsible for the decrease of maximum concentrations of hydrocarbon intermediate species.

Dimethoxymethane (DMM) called also methylal is a diether of interest because it has a potential as a neat or blended diesel fuel. The earliest tests were performed in a diesel engine Caterpillar and a 20 % blend of methylal in diesel fuel was shown to reduce smoke opacity by about 50 % at start-up and high idle [6-7]. More recently, a fuel consisting of 15 % methylal blended in ultra-low sulfur diesel was tested in a Daimler-Benz turbodiesel and it emitted 52 % lower particulate matter and 4 % lower oxides of nitrogen compared to a conventional diesel fuel [8]. Vertin et al. [9] have performed steady state engine tests using an unmodified turbocharged diesel engine and have demonstrated substantial reductions of particulate matter emissions for 10 % to 30 % blends of methylal in diesel fuel. Cheng et al. [10] have evaluated the effect of methylal-in-diesel blends on particulate matter emission with a diesel engine: the presence of methylal reduces the total

particle mass concentration, as well as the particle number density and the mean particle diameter.

In the area of flames studies, Gerber et al. [11] recently studied the impact of methylal addition into acetylene and ethylene overventilated diffusion flames. Laser induced incandescence was used to measure soot volume fractions within the flames and it was shown that these last parameters increase with an admixture of up to 10 % to 15 % of methylal before it falls more than proportional for higher percentages.

About the kinetics of methylal, few data are reported in the literature. Molera et al. [12-14] studied gas phase oxidation of methylal by molecular oxygen at moderate temperatures (491K-685K). They suggested a direct attack of DMM by  $O_2$  at low temperature but another process which could be a decomposition one becomes important at higher temperatures. Also, they concluded that hydroperoxides and peroxy radicals are produced at low temperature. Fernandez Sanchez et al. [15] studying between 371K and 573K hydrogen abstraction reactions by methyl radicals forming  $H_3C-O-CH-O-CH_3$  or  $H_2C-O-CH_2-O-CH_3$  radicals suggested several decomposition pathways according to their molecular structure. Wallington et al. [16], Porter et al. [17] and Vovelle et al. [18] measured the overall rate coefficient of the reaction of hydroxyl radicals with methylal at room temperature,  $3.2 \cdot 10^{12}$ ,  $2.8 \cdot 10^{12}$  and  $2.6 \cdot 10^{12} \text{ cm}^3 \text{ mol}^{-1} \text{ s}^{-1}$  respectively. In a comparative study, Porter et al. [17] showed that ethers and diethers with large molecular mass generally react faster than methylal. Very recently, Daly et al. [19] investigated oxidation of methylal in a jet-stirred reactor at 5.07 bar between 800K to 1200K and for equivalence ratios from 0.44 to 1.78. Concentration profiles vs temperature of stable compounds were measured and a detailed chemical model accounts quite well with experimental results.

Unfortunately, for diethoxymethane (DEM) called also ethylal, no data are available in the literature.

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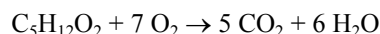
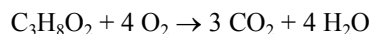
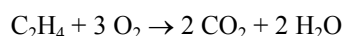
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## Specific Objectives

The main objective of this work is to compare the influence of methylal or ethylal addition on the structure of a slightly sooting premixed rich ethylene-oxygen-argon flame burning at 50 mbar and keeping constant the equivalence ratio ( $\phi$ ). Measurements of the concentration profiles of major species occurring in the reference flame (without additive) and in the methylal or ethylal added flames will provide more informations about the chemical role played by such compounds. Ultimately, the ability of methylal and ethylal to deplete soot precursors is checked experimentally.

## Experimental

Three rich flat premixed ethylene-oxygen-argon flames (with and without methylal or ethylal added), 2.50 in equivalence ratio ( $\phi$ ), have been stabilized at 50 mbar on a Spalding-Botha type burner, 8 cm in diameter. For the investigated flames, the initial flow velocity was identical, 40.3 cm/s. Initial molecular oxygen concentrations were kept constant and mole fractions of fuels (ethylene, methylal and ethylal) were adjusted to keep the equivalence ratio equal to 2.50 (Table 1). Taking into account the following reactions of complete combustion of  $C_2H_4$ ,  $C_3H_8O_2$  and  $C_5H_{12}O_2$ , an addition of  $\alpha$   $C_3H_8O_2$  must be compensated by the suppression of a quantity  $1,33\alpha$  of  $C_2H_4$  while an addition of  $\beta$   $C_5H_{12}O_2$  must be compensated by the suppression of a quantity  $2,33\beta$  of  $C_2H_4$ :



Methylal (99.79 % DMM, 0.203 % water) and ethylal (99.85 % DEM, 100 ppm BHT) from Lambiotte & Cie are colorless liquids at room pressure and temperature (boiling point: 42 °C and 88 °C). They were vaporized at reduced pressure (172 mm Hg and 116 mm Hg), at 20 °C and 55 °C respectively, through a calibrated capillary to ensure a constant flow rate.

Table 1. Flames inlet compositions

Flame	F2.50	F2.50E	F2.50M
$X_{C_2H_4}$	0.330	0.272	0.273
$X_{O_2}$	0.400	0.400	0.400
$X_{Ar}$	0.270	0.303	0.284
$X_{C_5H_{12}O_2}$	-	0.025	-
$X_{C_3H_8O_2}$	-	-	0.043
$\phi$	2.50	2.50	2.50
C/O ratio	0.83	0.79	0.76

$\phi$ , equivalence ratio

Identification and monitoring of signal intensity profiles of stable, atomic and radical species within the flames have been carried out by using molecular beam mass spectroscopy (M.B.M.S.). As usual, for every species, contributions either from fragmentation during

the electron impact, or from overlapping of species with similar mass have been kept low or taken into account. Conversion of signal intensities to mole fractions has been performed by using a calibrated mixture for stable compounds and by estimating ionization cross-sections for carbon-containing radicals and  $C_5$  to  $C_{10}$  species. Such estimation has been made by adding the individual ionization cross sections of the constituting atoms ( $Q_C = 1.8$ ,  $Q_O = 1.3$ ,  $Q_H = 0.65$ ).

Mole fraction profiles of the following species have been monitored in all investigated flames:  $H_2$ ,  $CH_3$  (methyl radical),  $CH_4$  (methane),  $H_2O$ ,  $C_2H_2$  (acetylene),  $C_2H_4$  (ethylene),  $CO$ ,  $CH_2O/C_2H_6$  (formaldehyde/ethane),  $O_2$ ,  $C_3H_3$  (propargyl radical),  $C_3H_4$  (allene + propyne),  $Ar$ ,  $C_3H_5$  (propenyl radical),  $CH_2CO/C_3H_6$  (cetene/propylene),  $CO_2$ ,  $C_2H_4O/C_3H_8$  (ethylene oxide/propane),  $C_4H_2$  (diacetylene),  $C_4H_4$  (vinylacetylene),  $C_4H_6$  (butadiene),  $C_4H_8$  (butene),  $C_4H_{10}/C_3H_6O$  (butane/propylene oxide),  $C_5H_4$ ,  $C_5H_6$  (cyclopentadiene),  $C_6H_2$  (triacetylene),  $C_6H_4$ ,  $C_6H_6$  (benzene),  $C_7H_8$  (toluene),  $C_6H_6O$  (phenol),  $C_8H_6$  (phenylacetylene),  $C_8H_8$  (styrene),  $C_9H_8$  (indene) and  $C_{10}H_8$  (naphthalene).

In addition, profiles of some supplementary species ( $CH_3O$  (methoxyl radical),  $C_2H_4O_2$  (methyl formate) and obviously  $C_3H_8O_2$  (methylal)) have been recorded only in flame F2.50M. Moreover, other species like  $CH_3CHO$  (acetaldehyde),  $C_2H_5O$  (ethanolate radical),  $C_2H_6O$  (ethanol),  $C_3H_7O$ ,  $C_2H_5OCH_2OH$  and  $C_5H_{12}O_2$  (ethylal) have been detected only in flame F2.50E.

Signal intensities of O and OH species have not been recorded free of interferences; their m/e are very close to those of  $CH_4$  and  $^{13}CH_4$  respectively. Monitoring of hydrogen atoms was outside of the mass range of the mass spectrometer (2-1000 a.m.u.).

Gas chromatography has been used as a complementary technique to identify the precise structure of some hydrocarbon species.

Final flame temperatures, measured by using Pt/PtRh10% coated thermocouples 0.1 mm in diameter and positioned in front of the sampling cone tip at 0.3-0.5 mm distance, are similar in all investigated flames and amount to 1800 K (Fig. 1). Radiation losses were corrected by the electrical compensation method.

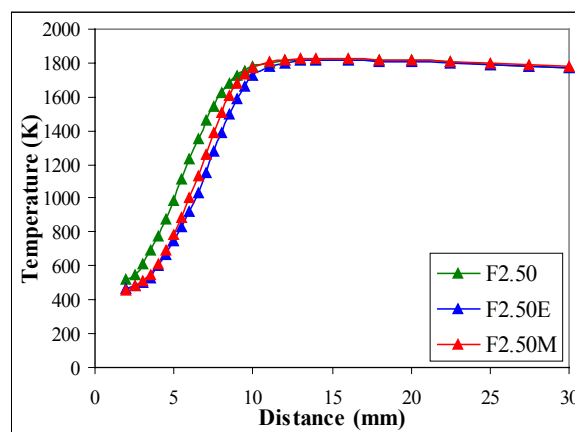


Fig. 1. Comparison of temperature profiles in all investigated flames.

The individual temperature profiles have been superimposed with the mole fraction profiles scale ( $z$ ) by comparison with the water mole fraction profile by using the equation:

$$T_z = T^0 + [(X_{H_2O})_z / (X_{H_2O})_{max}] (T_{max} - T^0)$$

$T_{max}$ ,  $T_z$  and  $T^0$  are the maximum, local and initial temperatures, respectively and  $(X_{H_2O})_{max}$  and  $(X_{H_2O})_z$  are the maximum and local mole fractions of water

## Results and discussion

Two kinds of results are gathered in this work:

1. the effect of methylal or ethylal addition on the experimental structure of the  $C_2H_4$ - $O_2$ -Ar flame
2. the influence of the initial C/O ratio in the fresh gases of the three investigated flames

### Effect of methylal or ethylal addition

The presence of 4.3 % of methylal or 2.5 % of ethylal in replacement of some ethylene in the flames F2.50M and F2.50E leads to a slight decrease of the burning velocity. This phenomenon involves a shift of the flame front respectively about 0.5 mm and 1 mm downstream from the burner as it is illustrated by the mole fraction profiles of  $C_2H_4$  (Fig. 2).

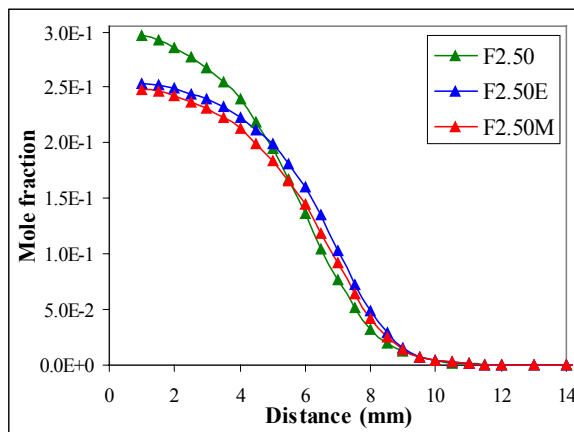


Fig. 2. Comparison of ethylene mole fraction profiles in all investigated flames.

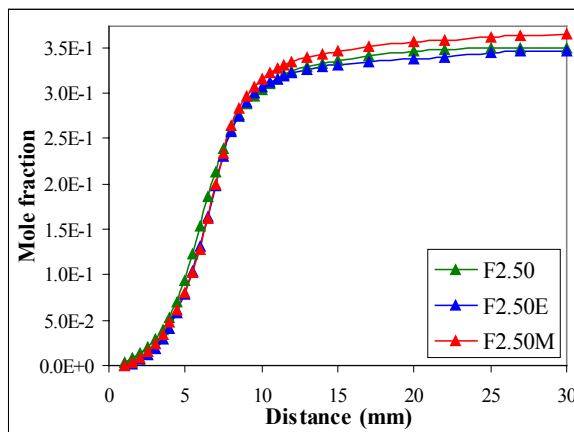


Fig. 3. Comparison of carbon monoxide mole fraction profiles in all investigated flames.

The partial replacement of  $C_2H_4$  by  $C_3H_8O_2$  leads in the burnt gases (at 30mm from the burner) to a decrease of  $H_2$  (9 %) but to an increase of  $CO_2$  (5 %),  $CO$  (4 %) and  $H_2O$  (18 %) (Fig. 3). If  $C_5H_{12}O_2$  is added to the flame in place of some  $C_2H_4$ , the effects are more moderate: decrease of  $H_2$  (3 %) and  $CO$  (1 %) and increase of  $CO_2$  (5 %) and  $H_2O$  (6 %) (Fig. 3).

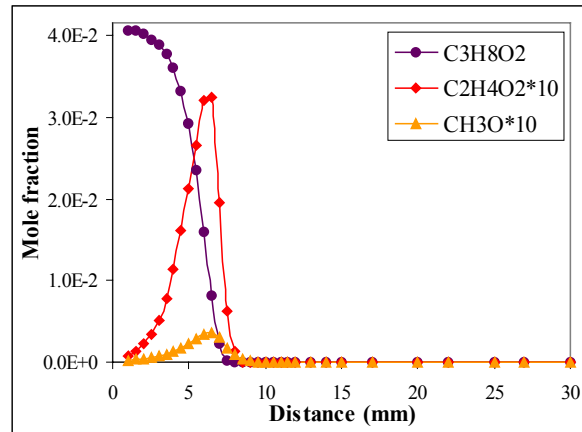
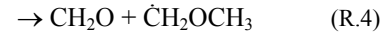
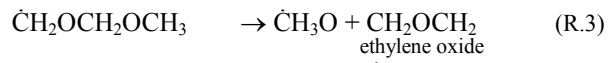
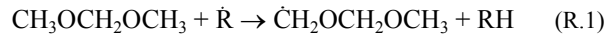


Fig. 4. Mole fraction profiles of  $C_3H_8O_2$ ,  $C_2H_4O_2$  and  $CH_3O$  in flame F2.50M.

The shape of the mole fraction profiles of  $C_3H_8O_2$  and  $C_5H_{12}O_2$  remains similar to that of  $C_2H_4$  (Fig. 4). Nevertheless,  $C_3H_8O_2$  and  $C_5H_{12}O_2$  are consumed more rapidly than  $C_2H_4$  and  $O_2$ .

Moreover, important supplementary reactions from methylal consumption can already be suggested:



where R is a radical  $\dot{H}$ ,  $\dot{O}H$  or  $\dot{C}H_3$

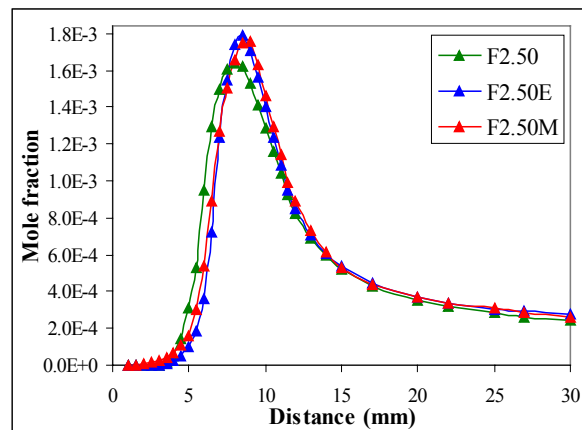
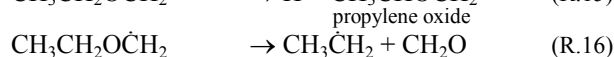
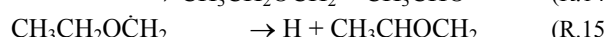
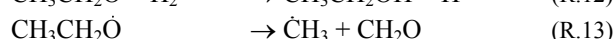
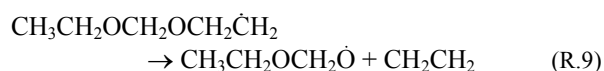
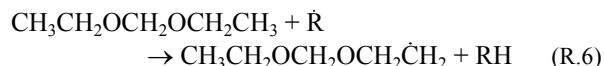


Fig. 5. Comparison of methyl radical mole fraction profiles in all investigated flames.

Indeed, two species, methoxy radical  $CH_3O$  (R.3) and methyl formate  $HCOOCH_3$  ( $C_2H_4O_2$ ) (R.5), are detected in flame F2.50M (Fig. 4) as well as a larger

maximum concentration of CH<sub>3</sub> (7 %) (Fig. 5). Unfortunately, ethylene oxide (m/e = 44) (R.3) or its isomer could not be detected due to the large presence of C<sub>3</sub>H<sub>8</sub> at the same molecular mass.

Supplementary reactions from ethylal consumption can also be suggested:



where  $\dot{\text{R}}$  is a radical  $\dot{\text{H}}$ ,  $\dot{\text{O}}\text{H}$  or  $\dot{\text{C}}\text{H}_3$

Indeed, supplementary species like C<sub>2</sub>H<sub>5</sub>O (R.11-13), C<sub>2</sub>H<sub>6</sub>O (R.12), C<sub>3</sub>H<sub>7</sub>O (R.14) and C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> (R.10) are detected in flame F2.50E as well as larger maximum signals for CH<sub>3</sub> (R.9) (Fig. 5), C<sub>2</sub>H<sub>6</sub>/CH<sub>2</sub>O (m/e = 30) (R.11, 13 and 16), C<sub>3</sub>H<sub>8</sub>/C<sub>2</sub>H<sub>4</sub>O/CH<sub>3</sub>CHO (m/e = 44) (R.14) and C<sub>4</sub>H<sub>10</sub>/C<sub>3</sub>H<sub>6</sub>O (m/e = 58) (R.15). However, ethyl formate HCOOCH<sub>2</sub>CH<sub>3</sub> (R.17) has not been detected; it may suggest that reaction R.8 is negligible.

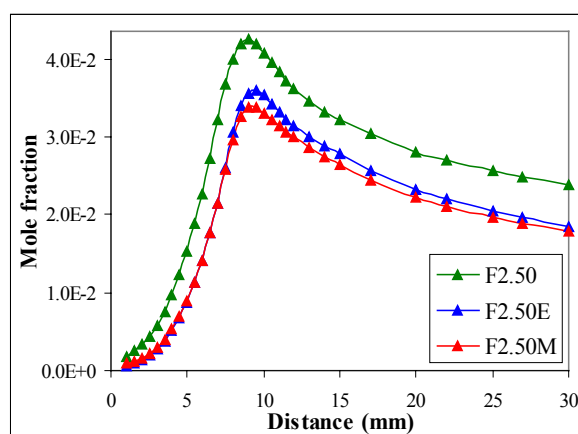


Fig. 6. Comparison of acetylene mole fraction profiles in all investigated flames.

The link between CH<sub>3</sub> and CH<sub>4</sub> quantities through the reaction  $\text{CH}_3 + \text{H}_2 \rightleftharpoons \text{CH}_4 + \text{H}$  does not explain the increase of the maximum mole fraction of CH<sub>4</sub> (28 %) in flame F2.50M (Fig. 5). But if R is CH<sub>3</sub> in reactions 1 and 2, a supplementary formation of CH<sub>4</sub> can occur. On the contrary, in flame F2.50E, the link between CH<sub>3</sub>

(+ 9 %) and CH<sub>4</sub> (+ 8 %) quantities through an equilibrium is established.

Most of the time, maximum mole fractions of C<sub>2</sub> to C<sub>4</sub> hydrocarbon intermediates decrease by about 15 % to 30 % in presence of methylal and 5 % to 30 % in presence of ethylal (Figs. 6, 7). However, profiles of some of these species (C<sub>2</sub>H<sub>6</sub>, C<sub>3</sub>H<sub>6</sub>, C<sub>3</sub>H<sub>8</sub>, C<sub>4</sub>H<sub>8</sub> and C<sub>4</sub>H<sub>10</sub>) could not be measured free of interferences in all or at least one of the investigated flames.

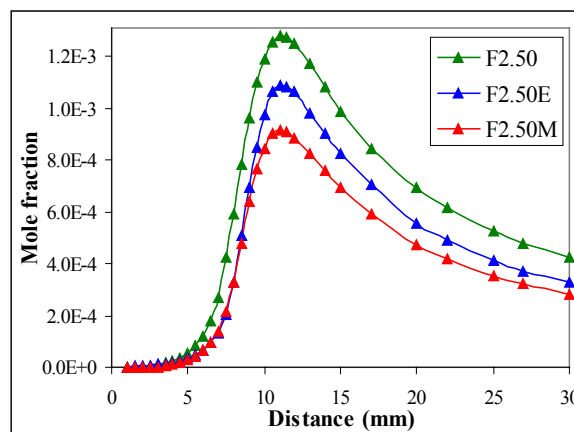


Fig. 7. Comparison of diacetylene mole fraction profiles in all investigated flames.

Maximum mole fractions of C<sub>5</sub> and C<sub>6</sub> hydrocarbon species are strongly affected by C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> or C<sub>3</sub>H<sub>12</sub>O<sub>2</sub> addition: average decreases between 30 % and 45 % and between 15 % and 30 % respectively (Fig. 8).

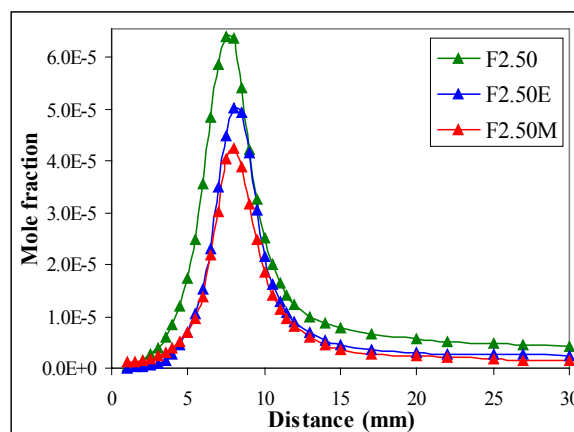


Fig. 8. Comparison of benzene mole fraction profiles in all investigated flames.

Mole fractions of C<sub>7</sub> to C<sub>10</sub> intermediates decrease somewhat more strongly: their maximum values are about 35 % to 50 % and 25 % to 45 % lower in the C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> or C<sub>3</sub>H<sub>12</sub>O<sub>2</sub> added flames respectively (Fig. 9).

Among the detected C<sub>1</sub> to C<sub>4</sub> hydrocarbon species remaining in the burnt gases region at 30 mm from the burner surface, CH<sub>3</sub> (+ 8 % and + 16 %) and CH<sub>4</sub> (- 4 % and - 12 %) are relatively less affected by methylal or ethylal addition respectively (Fig. 5). On the contrary, mole fractions of C<sub>3</sub>H<sub>3</sub>, C<sub>3</sub>H<sub>4</sub> and C<sub>4</sub>H<sub>4</sub> are lowered by about 15 % to 30 % in flame F2.50M and by about 30 % to 35 % in flame F2.50E. Moreover, concentrations of

species remaining in large amounts at 30 mm from the burner ( $C_2H_2$  and  $C_4H_2$ ) are about 25 % to 35 % and 20 % to 25 % lower in presence of  $C_3H_8O_2$  or  $C_5H_{12}O_2$  respectively (Figs. 6, 7).

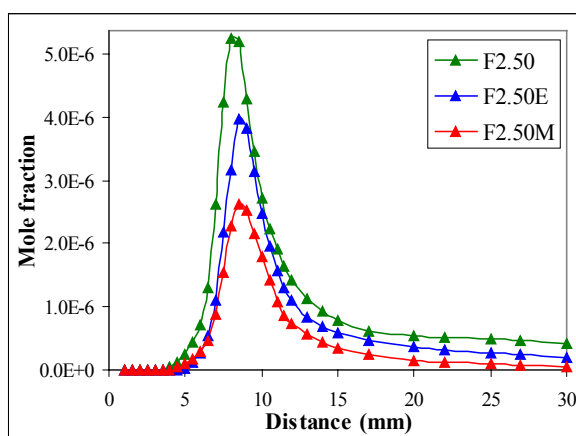


Fig. 9. Comparison of phenylacetylene mole fraction profiles in all investigated flames.

For most of  $C_5$  to  $C_6$  hydrocarbon intermediates remaining in the burnt gases region, mole fractions at 30 mm from the burner surface are about 50 % to 70 % lower in the methylal added flame and about 45 % to 50 % lower in the ethylal added flame (Fig. 8).

$C_7$  to  $C_{10}$  hydrocarbon species do not remain at 30 mm from the burner,  $C_8H_6$  excepted (Fig. 9). The mole fraction of the latest, is quite strongly modified by methylal (- 83 %) or ethylal (- 53 %) addition.

In general, most of species containing triple bonds ( $C_2H_2$ ,  $C_4H_2$ ,...) maintain larger concentrations in the burnt gases region than other hydrocarbon species. Such an effect could be ascribed to a low rate coefficient of hydrogen reactions with acetylenic type compounds.

#### Effect of the initial C/O ratio

As it is shown in table 1, the initial C/O ratio is different in the three investigated flames in spite of an identical equivalence ratio: F2.50 ( $C/O = 0.83$ ), F2.50E ( $C/O = 0.79$ ) and F2.50M ( $C/O = 0.76$ ). So, it could be interesting to observe if there is a link between the initial C/O ratio and the maximum concentrations of hydrocarbon intermediates.

Concerning  $C_1$  intermediates ( $CH_3$  and  $CH_4$ ), their mole fraction profiles are influenced directly by the presence of methylal or ethylal into the flames F2.50M and F2.50E in contrast to the flame F2.50 without additive (Fig. 5).

For heavier hydrocarbon species (Figs 6-9), comparing with the reference flame F2.50 ( $C/O = 0.83$ ), their maximum mole fractions are lower by 5 % to 45 % in flame F2.50E ( $C/O = 0.79$ ). In general, for a given species, the decrease is less pronounced than that (between 10 % and 50 %) observed in flame F2.50M ( $C/O = 0.76$ ) (Figs 6-9). Moreover, we observe a good linear correlation between maximum mole fractions measured for most of  $C_2$  to  $C_{10}$  species and the initial C/O ratio of the corresponding flame (Figs 10-12).

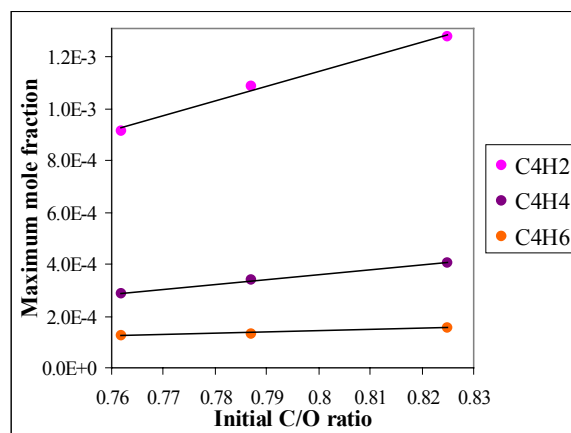


Fig. 10. Evolution of maximum mole fractions of  $C_4$  species according to the initial C/O ratio

However, for  $C_2$  to  $C_3$  intermediates, such a linear correlation is only valid for  $C_2H_2$  and  $C_3H_5$  species with very good coefficients of determination ( $R^2 = 0.9895$  and  $R^2 = 0.9980$  respectively). But,  $C_3H_3$  and  $C_3H_4$  seem to be more sensitive in F2.50E than in F2.50M and species like  $C_2H_6$ ,  $C_3H_6$  and  $C_3H_8$  could not be measured free of interferences in all or at least one of the investigated flames.

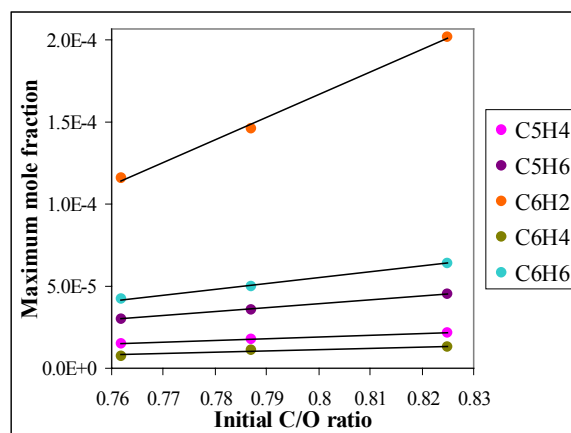


Fig. 11. Evolution of maximum mole fractions of  $C_5$  and  $C_6$  species according to the initial C/O ratio

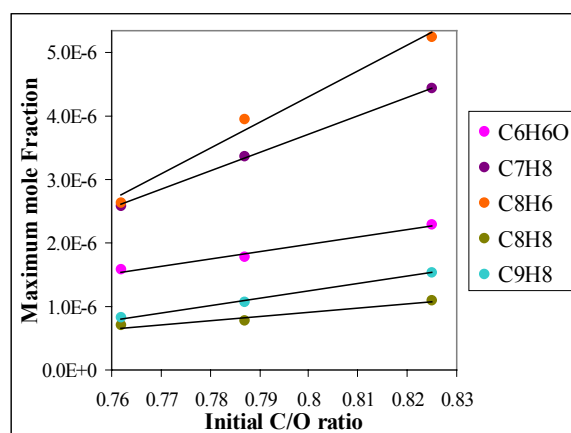


Fig. 12. Evolution of maximum mole fractions of  $C_6H_6O$  and  $C_7$  to  $C_9$  species according to the initial C/O ratio

On the contrary, almost all C<sub>4</sub> to C<sub>10</sub> species exhibit a linear correlation of measured maximum mole fractions with the initial C/O ratio of the corresponding flame (C<sub>4</sub>H<sub>8</sub> and C<sub>4</sub>H<sub>10</sub> excepted which can not be measured free of interferences in all or at least one of the investigated flames). That correlation is very good for all C<sub>4</sub> to C<sub>6</sub> intermediates ( $R^2 \geq 0,9848$ ), C<sub>6</sub>H<sub>4</sub> excepted (Figs. 10, 11). For most of species with lower maximum mole fractions like C<sub>6</sub>H<sub>6</sub>O and C<sub>7</sub> to C<sub>10</sub> species (Fig. 12), results remain good ( $R^2 \geq 0,9781$ ). However, for C<sub>10</sub>H<sub>8</sub>, no linear correlation is observed.

Hydrocarbon intermediates levels in rich flames are governed, thus, mainly by the C/O ratio instead of the equivalence ratio when an oxygenated compound is added.

### Conclusions

An experimental flame structure investigation has been performed on slightly sooting rich premixed ethylene-oxygen-argon flames ( $\phi = 2.50$ ) with or without C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> or C<sub>5</sub>H<sub>12</sub>O<sub>2</sub> in partial replacement of C<sub>2</sub>H<sub>4</sub>. Because the final flame temperature is similar in all the flames, the chemical effects of the initial C/O ratio and of C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> or C<sub>5</sub>H<sub>12</sub>O<sub>2</sub> addition have been determined. The main conclusions are:

- Methylal or ethylal addition to the fresh gases inlet causes a shift downstream of the flame front and thus inhibits the flame.
- The replacement of some C<sub>2</sub>H<sub>4</sub> by C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> or C<sub>5</sub>H<sub>12</sub>O<sub>2</sub> is responsible for a decrease of the maximum mole fractions of the detected intermediate species. This phenomenon, more efficient in the case of C<sub>3</sub>H<sub>8</sub>O<sub>2</sub> addition, is still noticeable for C<sub>2</sub> to C<sub>4</sub> intermediates and becomes more efficient for C<sub>5</sub> to C<sub>10</sub> species.
- Although the equivalence ratio is identical ( $\phi = 2.50$ ) in the three investigated flames F2.50 (C/O = 0.83), F2.50E (C/O = 0.79) and F2.50M (C/O = 0.76), we observe a good linear correlation between maximum mole fractions measured for most of C<sub>2</sub> to C<sub>10</sub> intermediate species and the initial C/O ratio of the corresponding flame. It seems to indicate that the initial C/O ratio in the fresh gases mixtures better reflects the influence on maximum concentrations of hydrocarbon intermediates and soot precursors in rich flames when an oxygenated compound is added.

Such observations corroborate the impact of methylal blended diesel fuels on soot particulates formation. Indeed, a decrease of the initial C/O ratio keeping constant the equivalence ratio leads to lower concentrations of soot precursors. It indicates that adding strongly oxygenated fuels to the diesel will increase the number of C-O bonds in the region where it is sprayed and lower the local C/O ratio. Therefore the role of such oxygenated compounds is to bring in some oxygen in the fuel zone. The faster consumption of methylal and ethylal in premixed flames, i.e. at lower temperatures than ethylene, is an additional factor for fuel conversion. The higher vaporization rate of

methylal and ethylal compared to that of diesel is also a parameter which decreases the mixing time with air.

These experimental results provide data for future comparison with numerical modeling of a combustion mechanism of rich mixtures up to C<sub>10</sub> species.

### Acknowledgements

The authors are very grateful to the Ministère de la Région Wallone for the financial support (Grants n° 00/42884, 01/43257 and 02/43371).

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