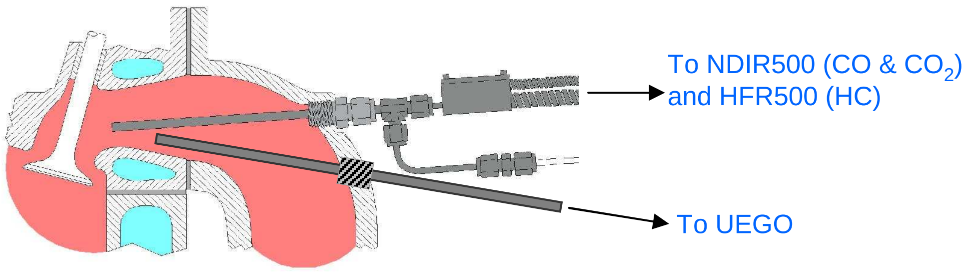
Measurement of cycle-by-cycle AFR using a fast response NDIR analyzer for cold start fuelling calibration applications.

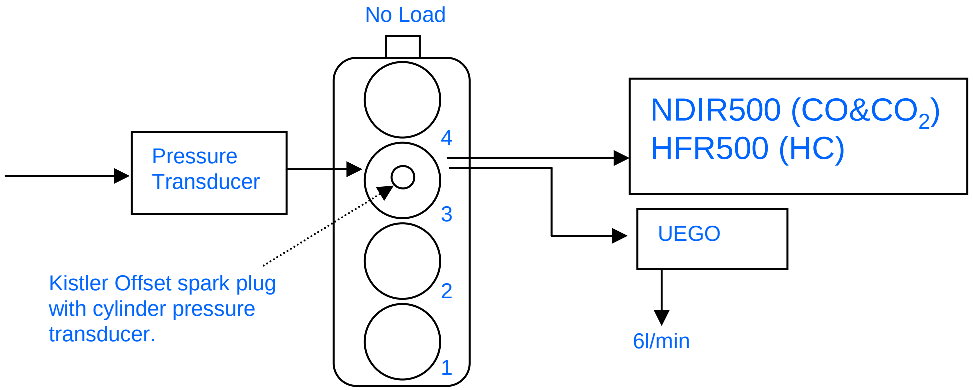
• CAMBUSTION •

Background

- Cold start remains a significant source of emissions.
- Emissions tend to be linked to poor combustion.
- Air: Fuel Ratio (AFR) is a key factor governing combustion quality. AFR normalised to stoichiometry gives λ.
- λ is critical in analysing and controlling emissions during cold start.

Experimental Setup:





Equipment:

- Engine. 1.8L,PFI.
- Wide band UEGO
- Cambustion NDIR500 (Fast CO and CO_2)
- Cambustion HFR500 (Fast HC)
- Kistler offset plug and pressure transducer.

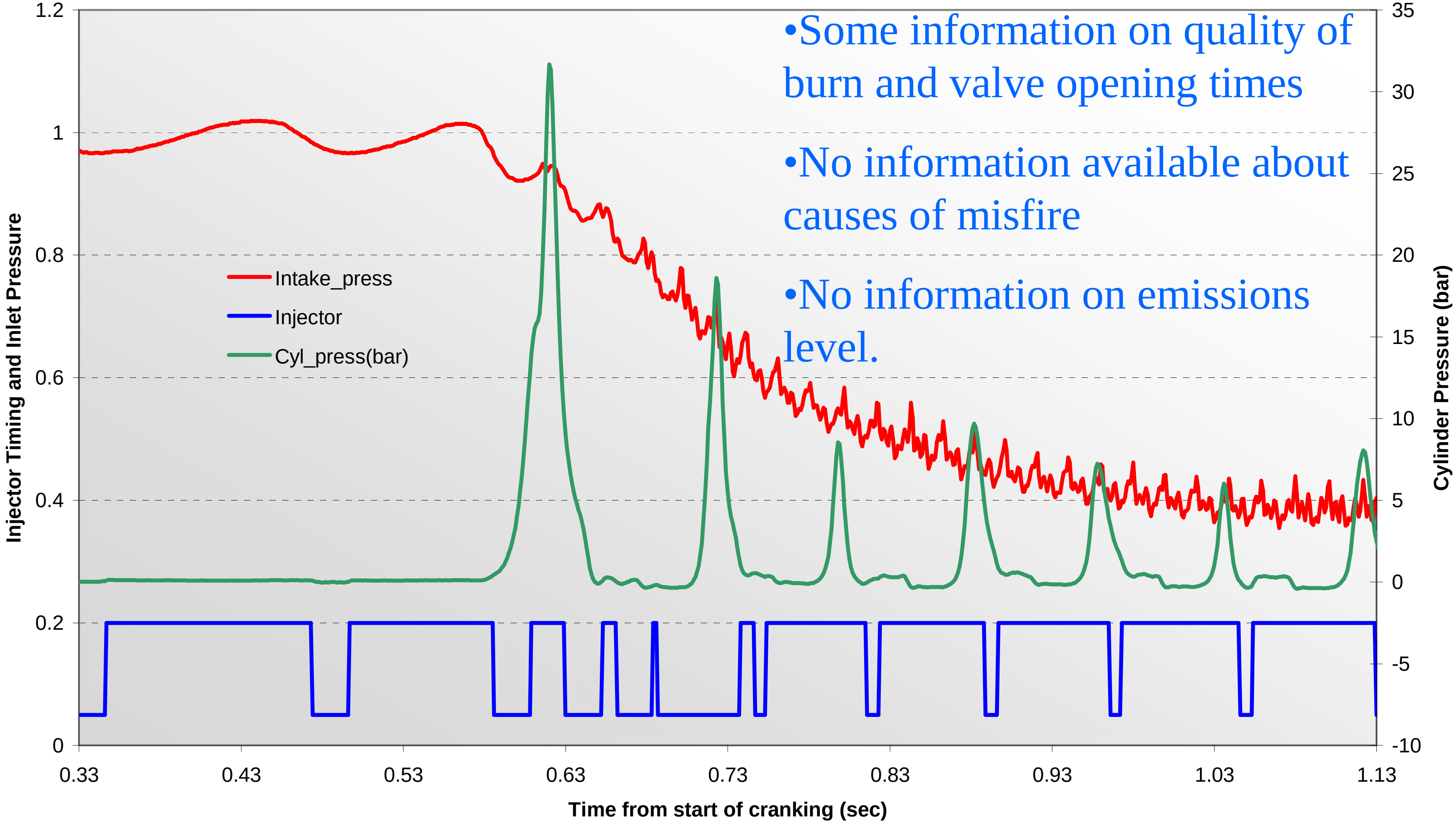
Engine data for first 6 strokes.

■Large concentration of fuel entering cold cylinder in liquid form is probable cause of misfires.

•Some information on quality of burn and valve opening times

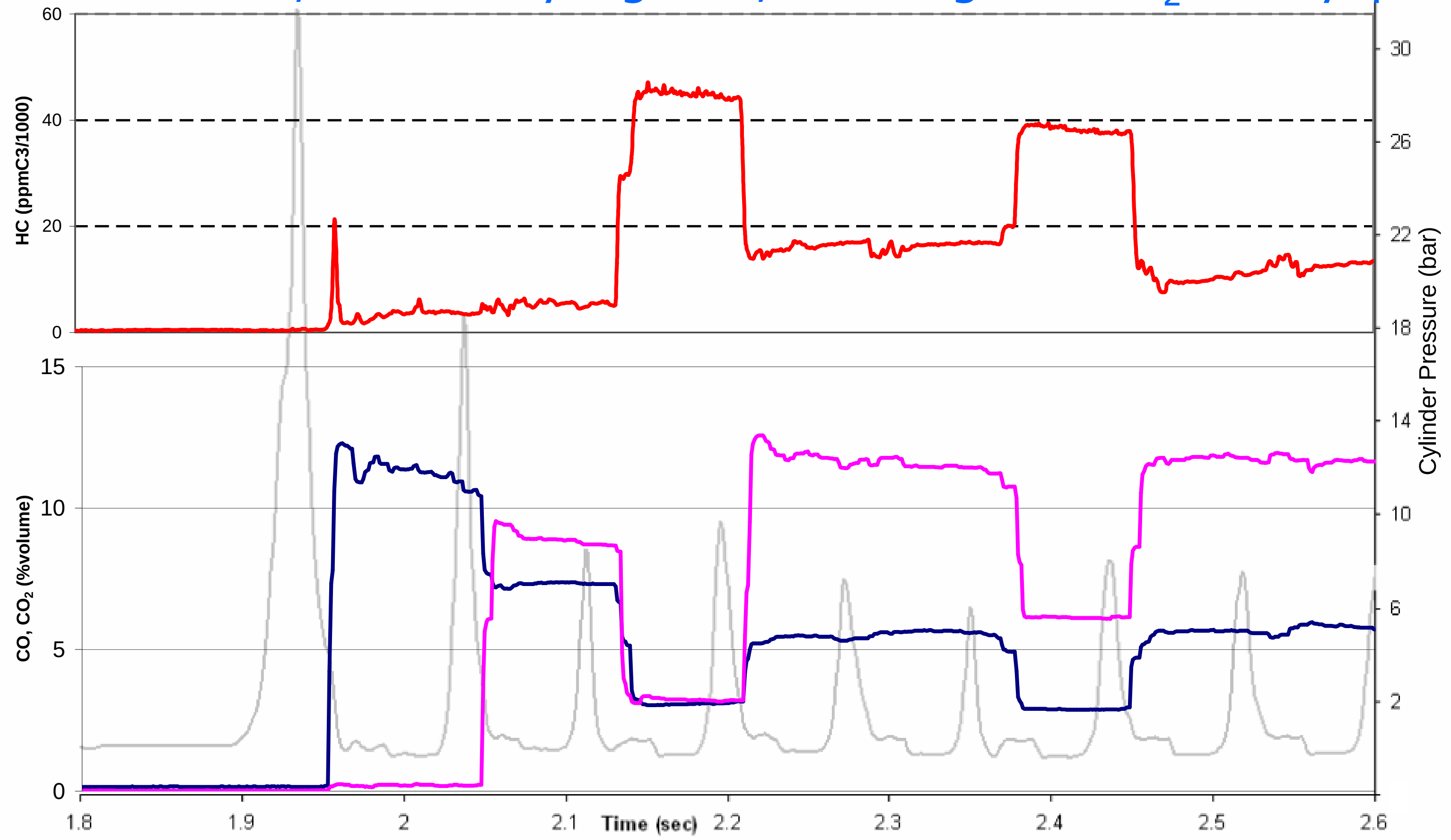
•No information available about causes of misfire

•No information on emissions level.



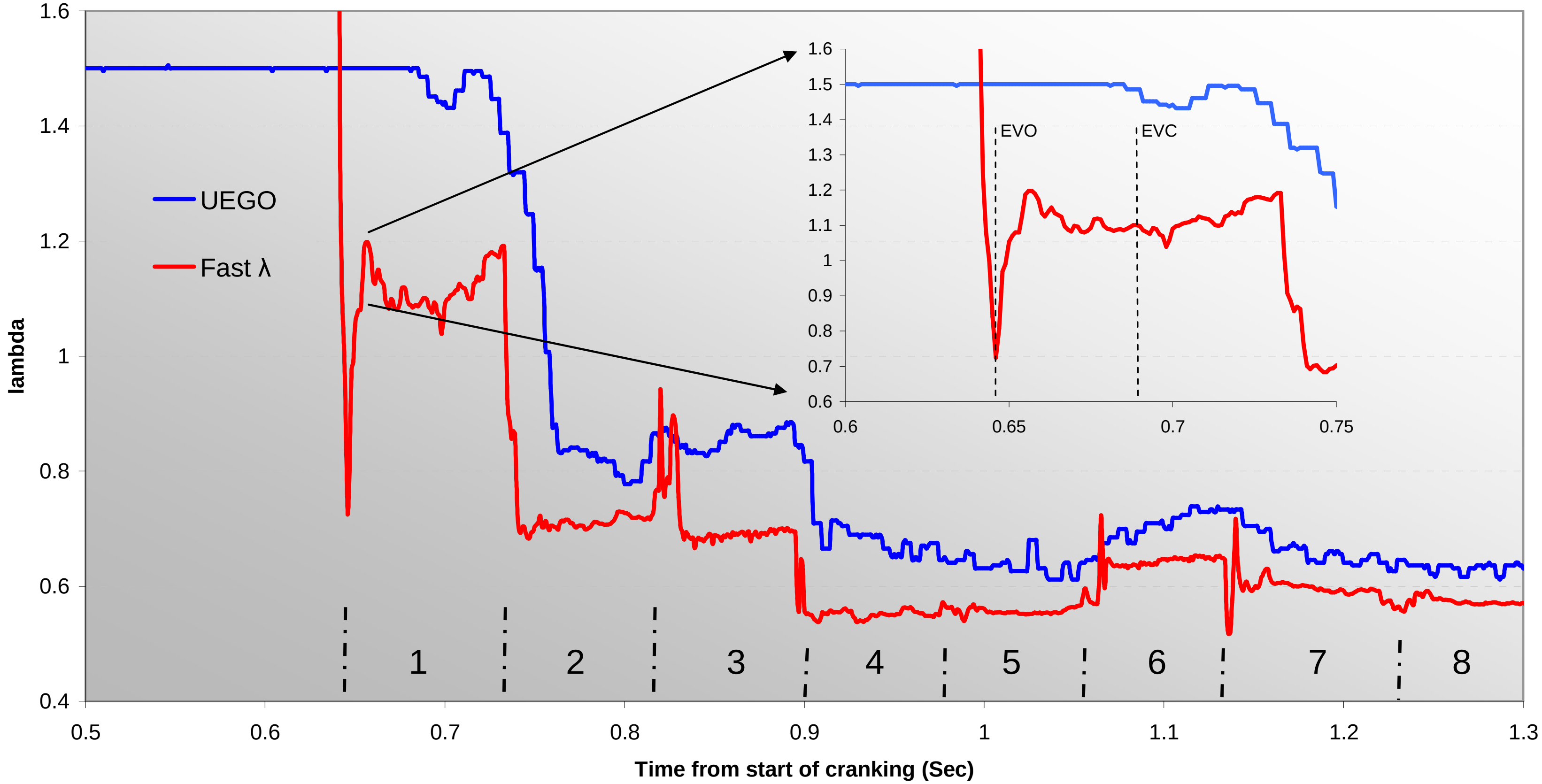
Raw Data acquired during cold start.

- Fast gas analysers able to distinguish each exhaust event.
- Late Burn stroke 1, High CO_2+very low CO suggest lean burn.
- Misfires Strokes 3,6 shown by high HC, reducing $CO+CO_2$ and cyl pressure.



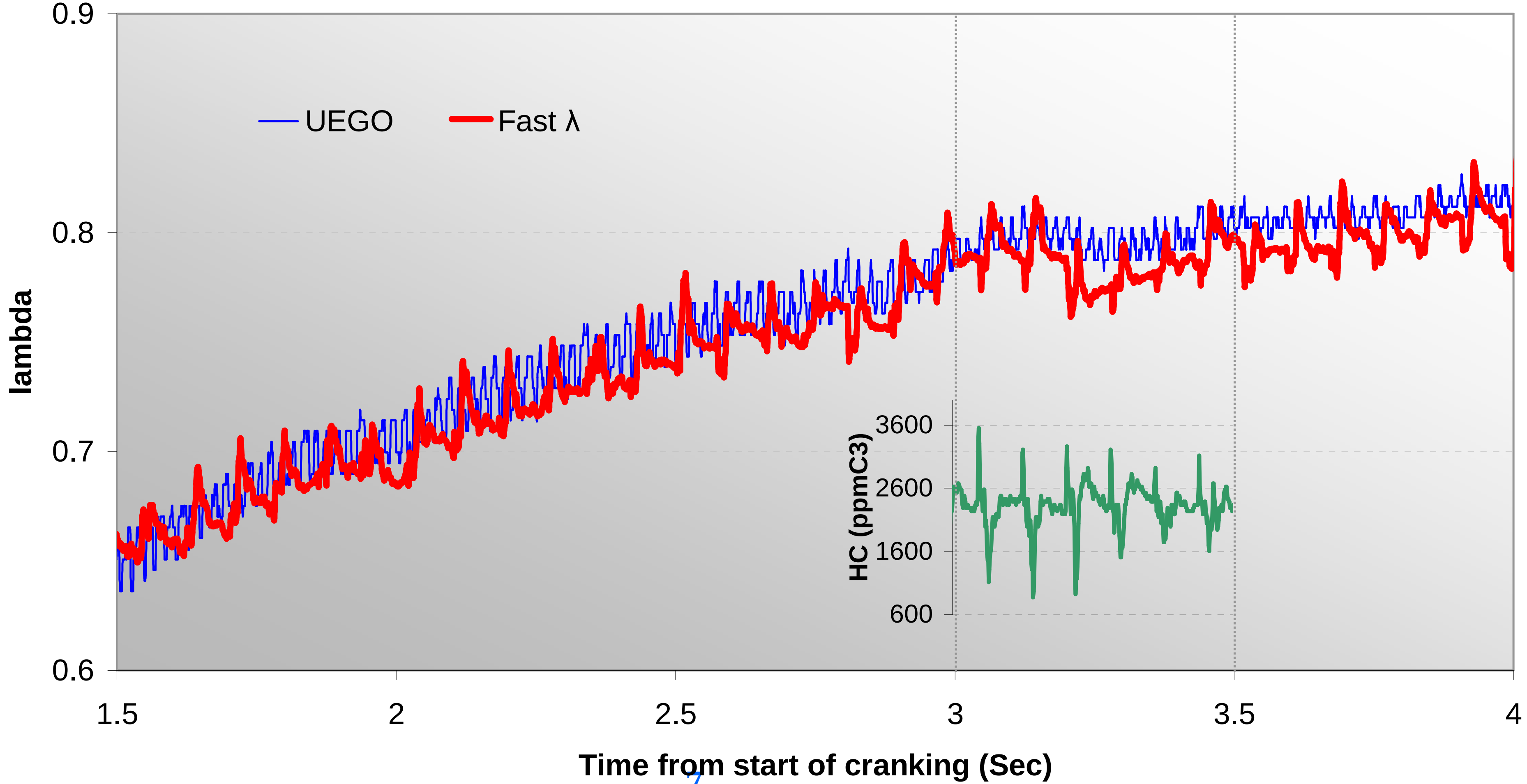
Post Processed data. Fast λ vs UEGO.

- UEGO output can be too lean in the presence of high HC concentrations due to surface effects.
- Calculating λ from combustion gases avoids this problem and allows for fast time resolution.

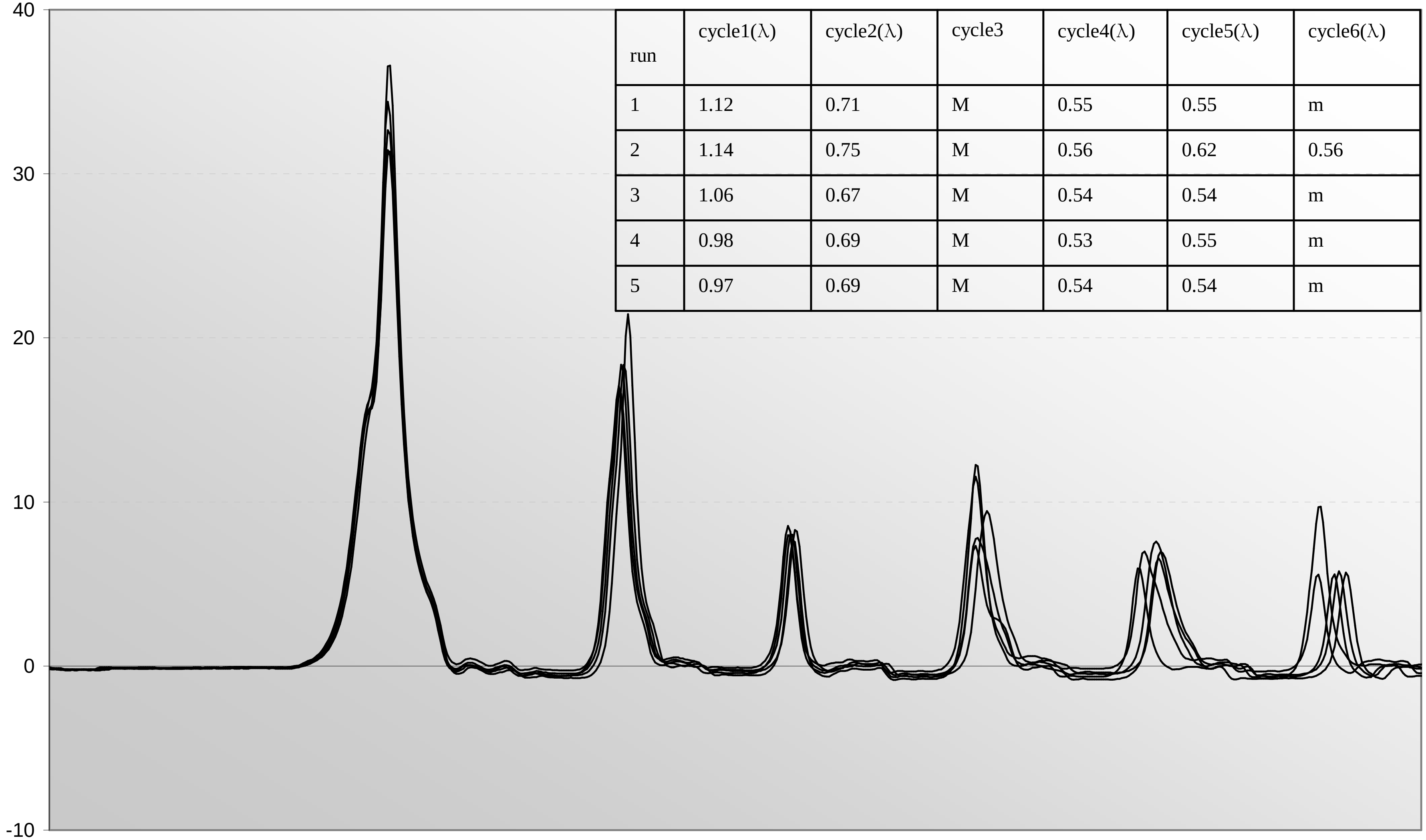


Post Processed Data – Fast λ and UEGO.

- Good agreement is seen when HC concentration is lower.



Repeatability



run	cycle1(λ)	cycle2(λ)	cycle3	cycle4(λ)	cycle5(λ)	cycle6(λ)
1	1.12	0.71	M	0.55	0.55	m
2	1.14	0.75	M	0.56	0.62	0.56
3	1.06	0.67	M	0.54	0.54	m
4	0.98	0.69	M	0.53	0.55	m
5	0.97	0.69	M	0.54	0.54	m

Equations used

In what follows, the assumption is that the actual (wet) mol fractions of CO and CO_2 are available.
If dry composition data is to be used, then the relationship

$$(gas)_{wet} = (1-(H_2O)).(gas)_{dry}$$

must be used. Since (H_2O) will not be known a priori, an iteration is required.

$$n_{O_2} = n + \frac{m}{4} - \frac{r}{2}$$ (mols O_2 required for complete combustion of one mol of fuel $C_nH_mO_r$)

$$n_p = \frac{n}{\left(n(HC)+(CO)+(CO_2)\right)}$$ (mols of products; $(HC),(CO),(CO_2)$ mol fractions; hydrcarbons assumed same composition as fuel(C_nH_m))

$$(H_2O) = \frac{m.\left(1/n_p - (HC)\right)}{2\left(1+\frac{(CO)}{K.(CO_2)}\right)}$$ (mol fraction H_2O; mol fraction)

(Eq 4.65 in Heywood includes the assumption that $n(HC) << (CO)+(CO_2)$)

$$(H_2) = \frac{(CO).(H_2O)}{K.(CO_2)}$$ (mol fraction H_2)

$$(O_2) = \frac{\left(1-(HC)-(1+\varphi/2)\left((CO)+(H_2O)\right)-(H_2)-(1+\varphi)(CO_2)+\frac{r\varphi}{2n_p}\right)}{(1+\varphi)}$$ (mol fraction O_2., $\varphi = 3.773$, mols N_2 per mol O_2 in air)

$$\lambda = \frac{n_p\left((CO)+2(CO_2)+2(O_2)+(H_2O)\right)-r}{2n_{O_2}}$$

or

$$\lambda = \frac{n_p}{2n_{O_2}(1+\varphi)}\left[2(1-(HC))-(CO)-m\left(1/n_p-(HC)\right)\frac{\left((CO)+0.5K(CO_2)\right)}{\left((CO)+K(CO_2)\right)}-\frac{r}{n_p}\right]$$