

| Sensor | FS1-1 | FS1-2 | FS1-3 | FS1-4 | FS1-5 | FS1-6 | FS2-1 | FS2-2 | FS2-3 | FS2-4 | FS2-5 | FS2-6 | FS3-1 | FS3-2 | FS3-3 | FS3-4 | FS3-5 | FS3-6 | FS4-1 | FS4-2 | FS4-3 | FS4-4 | FS4-5 | FS4-6 |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | #N/A | #N/A | IP0 | #N/A | #N/A | IP1 | #N/A | #N/A | IP2 | #N/A | #N/A | IP6 | #N/A | #N/A | #N/A | IP10 | #N/A | IP14 | #N/A | IP18 | #N/A | #N/A | IP22 | IP23 |
| | | | | | | | | | RAKE | | | | | | RAKE | | | | RAKE | | | RAKE | | |

| Sensor | NS1-1 | NS1-2 | NS1-3 | NS1-4 | NS1-5 | NS1-6 | NS2-1 | NS2-2 | NS2-3 | NS2-4 | NS2-5 | NS2-6 | NS3-1 | NS3-2 | NS3-3 | NS3-4 | NS3-5 | NS3-6 | NS4-1 | NS4-2 | NS4-3 | NS4-4 | NS4-5 | NS4-6 |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | #N/A | #N/A | TC0 | TC3 | TC1 | TC4 | #N/A | TC2 | KU3 | #N/A | OP0 | #N/A | KU6 | TC6 | #N/A | KU5 | OP1 | KU0 | #N/A | OP2 | TC15 | #N/A | OP3 | KU7 |
| | | | | | | | | | TC9 | RAKE | | | TC7 | | RAKE | | | | RAKE | | | RAKE | | |

| Further Instrumentation | | |
|-------------------------|--------|---------|
| Location | Sensor | Working |
| TS1-1 | TC8 | |
| TS2-1 | TC10 | |
| TS3-1 | TC12 | |
| TS4-1 | TC14 | |
| R1-1 | IP3 | |
| R1-2 | IP4 | |
| R1-3 | IP5 | |
| R2-1 | IP7 | |
| R2-2 | IP8 | |
| R2-3 | IP9 | |
| R3-1 | IP11 | |
| R3-2 | IP12 | |
| R3-3 | IP13 | |
| R4-1 | IP15 | |
| R4-2 | IP16 | |
| R4-3 | IP17 | |
| R5-1 | IP19 | |
| R5-2 | IP20 | |
| R5-3 | IP21 | |
| KU3 | TC9 | |
| KU4 | #N/A | |
| KU6 | TC5 | |
| pitot | TC11 | |

| | |
|---------------------|------------|
| Ionisation Probe | Light Blue |
| Pressure Transducer | Yellow |
| Thermocouple | Orange |
| Optical Probe | Red |

| Item | Location | DAQ | Channel | Measurement | Instrument | Supplier | Range | Signal | Excitation | S/R |
|------|----------|------|---------------|---------------------------|---------------------|------------|--------|-------------|------------|---------|
| IP0 | FS1-3 | PXIe | PXI Slot2/ai0 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP1 | FS1-6 | PXIe | PXI Slot2/ai1 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP2 | FS2-3 | PXIe | PXI Slot2/ai2 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP3 | R1-1 | PXIe | PXI Slot2/ai3 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP4 | R1-2 | PXIe | PXI Slot2/ai4 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP5 | R1-3 | PXIe | PXI Slot2/ai5 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP6 | FS2-6 | PXIe | PXI Slot2/ai6 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP7 | R2-1 | PXIe | PXI Slot2/ai7 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP8 | R2-2 | PXIe | PXI Slot6/ai0 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP9 | R2-3 | PXIe | PXI Slot6/ai1 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP10 | FS3-4 | PXIe | PXI Slot6/ai2 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP11 | R3-1 | PXIe | PXI Slot6/ai3 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP12 | R3-2 | PXIe | PXI Slot6/ai4 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP13 | R3-3 | PXIe | PXI Slot6/ai5 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP14 | FS3-6 | PXIe | PXI Slot6/ai6 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP15 | R4-1 | PXIe | PXI Slot6/ai7 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP16 | R4-2 | PXIe | PXI Slot7/ai0 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP17 | R4-3 | PXIe | PXI Slot7/ai1 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP18 | FS4-2 | PXIe | PXI Slot7/ai2 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP19 | R5-1 | PXIe | PXI Slot7/ai3 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP20 | R5-2 | PXIe | PXI Slot7/ai4 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP21 | R5-3 | PXIe | PXI Slot7/ai5 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP22 | FS4-5 | | PXI Slot7/ai6 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| IP23 | FS4-6 | PXIe | PXI Slot7/ai7 | Flame Presence | Ionisation Probe | Bruce Ewan | TBC | -5 to 5V | 60V | 100 kHz |
| OP0 | NS2-5 | PXIe | PXI1Slot4/ai0 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| OP1 | NS3-5 | PXIe | PXI1Slot4/ai1 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| OP2 | NS4-2 | PXIe | PXI1Slot4/ai2 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| OP3 | NS4-5 | PXIe | PXI1Slot4/ai3 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| OP4 | NS4-5 | PXIe | PXI1Slot4/ai4 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| OP5 | | PXIe | PXI1Slot4/ai5 | Flame Presence | Optical Probe | Bruce Ewan | TBC | -5 to 5V | 30V | 100 kHz |
| TC0 | NS1-3 | PXIe | SC1Mod4/Wall | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC1 | NS1-5 | PXIe | SC1Mod4/ai1 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC2 | NS2-2 | PXIe | SC1Mod4/ai2 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC3 | NS1-4 | PXIe | SC1Mod4/ai3 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC4 | NS1-6 | PXIe | SC1Mod4/ai4 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC5 | Ku6 | PXIe | SC1Mod4/ai5 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC6 | NS3-2 | PXIe | SC1Mod4/ai6 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC7 | | PXIe | SC1Mod4/ai7 | Gas Temperature (Wall) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC8 | TS1-1 | PXIe | SC1Mod4/ai8 | Temperature (surface) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC9 | KU3 | PXIe | SC1Mod4/ai9 | Temperature (kulite body) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC10 | TS2-1 | PXIe | SC1Mod4/ai10 | Temperature (surface) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC11 | pitot | PXIe | SC1Mod4/ai11 | Temperature (kulite body) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC12 | TS3-1 | PXIe | SC1Mod4/ai12 | Temperature (surface) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC13 | | PXIe | SC1Mod4/ai13 | Temperature (kulite body) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC14 | TS4-1 | PXIe | SC1Mod4/ai14 | Temperature (surface) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| TC15 | NS4-3 | PXIe | SC1Mod4/ai15 | Temperature (pitot) | K-Type Thermocouple | TC-Direct | 1100°C | Conditioned | None | 5 kHz |
| KU0 | NS3-6 | PXIe | SC1Mod1/ai0 | Pressure | Kulite | | | | | 100 kHz |
| KU1 | | PXIe | SC1Mod1/ai1 | Pressure | Kulite | | | | | 100 kHz |
| KU2 | | PXIe | SC1Mod1/ai2 | Pressure | XTEH-190M-50BARA | Kulite | | 0-100 mV | | 100 kHz |
| KU3 | NS2-3 | PXIe | SC1Mod1/ai3 | Pressure | Kulite | | | | | 100 kHz |
| KU4 | | PXIe | SC1Mod1/ai4 | Pressure | Kulite | | | | | 100 kHz |
| KU5 | NS3-4 | PXIe | SC1Mod1/ai5 | Pressure | Kulite | | | | | 100 kHz |
| KU6 | NS3-1 | PXIe | SC1Mod1/ai6 | Pressure | Kulite | | | | | 100 kHz |
| KU7 | NS4-6 | PXIe | SC1Mod1/ai7 | Pressure | Kulite | | | | | 100 kHz |
| PB1 | | PXIe | | Pressure | 113824 | PCB | 68 bar | 0-5 V | 20-30 V | 1 MHz |
| PB2 | TS3-6 | PXIe | PXI Slot3/ai0 | Pressure | 113825 | PCB | 68 bar | 0-5 V | 20-30 V | 1 MHz |

| | |
|---------------------|---------------|
| Date | 16 April 2015 |
| Time | 14:10 |
| Test Number | 40 |
| Mixture Composition | 60%H2/40% CH4 |
| Ambient Temperature | 8 oC |
| Ambient Pressure | 969 mbar |
| Wind Speed | 0 m/s |
| Wind direction | |
| Relative Humidity | 65.00% |
| Equivalence Ratio | 0.66 |

General Comments: (weather, rig configuration)

Weather: Cool but sunny and dry.
 Tube configuration:
 4 x 3m tube sections
 igniter 250mm from beginning of tube section

Test with 15 rows of congestion (row 8 on central flange with 7 rows projecting upstream into tube 2 and 7 rows projecting downstream into tube 3. This is a repeat of Test 31 and is the highest EQR tested for this 40/60 CH4/H2 mixture. By comparison this combustion event is relatively weak in intensity with a peak pressure of 1353 mbar compared previously with 3016 mbar. Note that for this group of tests, the IPs sensor tips were treated to a blowtorch treatment raising them to yellow heat to attempt to remove any residual moisture. This was found in pre-checks to greatly improve their sharpness of performance. It is noted however that the IP signals carry more noise than usual, making flame arrival difficult for some positions. The complexity of the flame propagation leads to some uncertainty in the calculation of this for some locations. The flame speeds are very modest (~100 -200 m/s) and the overall combustion event appears weaker than that for test 31. This is also confirmed by the absence of a flame on the exit OP3. It is also noted that the photographic record did not show flame front emergence from the tube exit. It should also be noted that the tdms file for this case contains two sets of data as this case was repeated during the data collection. The second data set shows very similar combustion behaviour, e.g. in terms of peak pressure and OP behaviour.

Headlines

Max overpressure
 mbar

Max. flame speed
 m/s
 [ionisation probes]

Max. temperature
 °C

Mass Flow
 kg/s

m/s
 [optical probes]

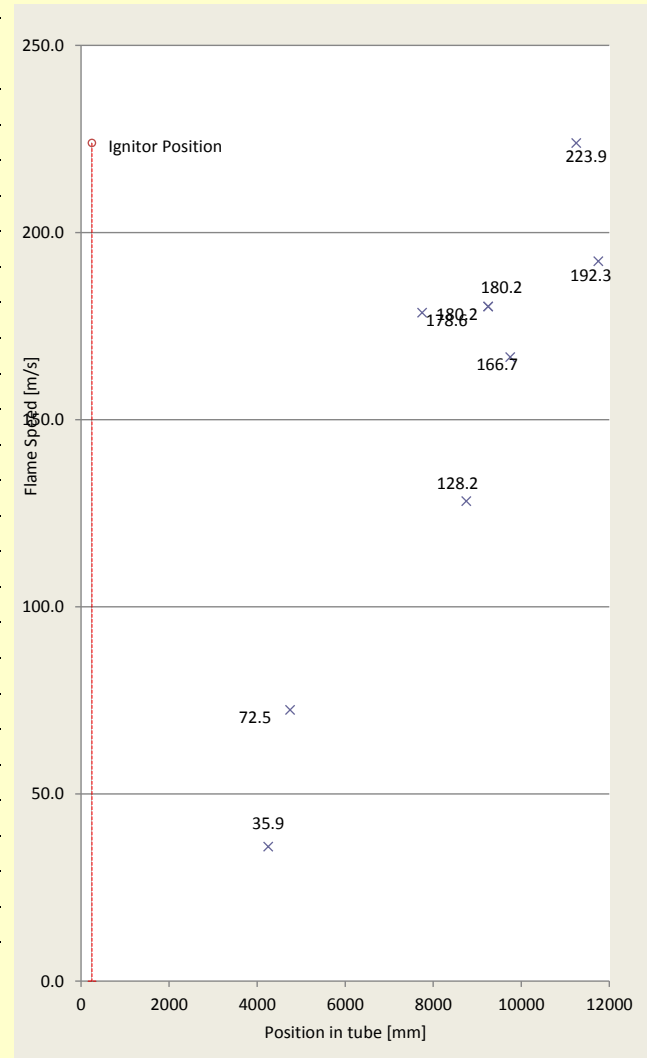
Initial Temperature
 °C

Location of igniter mm

Time of ignition seconds

| IP Number | Location label | Data Name | Position in tube (mm) | Flame arrival time (s) | Avg Flame speed from last sensor (m/s) |
|-----------|----------------|-------------|-----------------------|------------------------|--|
| REF | #N/A | Flameion_0 | #N/A | | |
| IP1 | FS1-6 | Flameion_1 | 2750 | | |
| IP2 | FS2-3 | Flameion_2 | 4250 | 8.5147 | 35.9 |
| IP3 | R1-1 | Flameion_3 | 4750 | 8.5216 | 72.5 |
| IP4 | R1-2 | Flameion_4 | 4750 | 8.5179 | |
| IP5 | R1-3 | Flameion_5 | 4750 | NS | |
| IP6 | FS2-6 | Flameion_6 | 5750 | NS | |
| IP7 | R2-1 | Flameion_7 | 6000 | 8.5054 | |
| IP8 | R2-2 | Flameion_8 | 6000 | disconnected | |
| IP9 | R2-3 | Flameion_9 | 6000 | NS | |
| IP10 | FS3-4 | Flameion_10 | 7750 | 8.5332 | 178.6 |
| IP11 | R3-1 | Flameion_11 | 7250 | 8.5304 | |
| IP12 | R3-2 | Flameion_12 | 7250 | NS | |
| IP13 | R3-3 | Flameion_13 | 7250 | NS | |
| IP14 | FS3-6 | Flameion_14 | 8750 | 8.5410 | 128.2 |
| IP15 | R4-1 | Flameion_15 | 9250 | 8.5415 | 180.2 |
| IP16 | R4-2 | Flameion_16 | 9250 | 8.5415 | 180.2 |
| IP17 | R4-3 | Flameion_17 | 9250 | NS | |
| IP18 | FS4-2 | Flameion_18 | 9750 | 8.5470 | 166.7 |
| IP19 | R5-1 | Flameion_19 | 10750 | NS | |
| IP20 | R5-2 | Flameion_20 | 10750 | NS | |
| IP21 | R5-3 | Flameion_21 | 10750 | NS | |
| IP22 | FS4-5 | Flameion_22 | 11250 | 8.5537 | 223.9 |
| IP23 | FS4-6 | Flameion_23 | 11750 | 8.5563 | 192.3 |

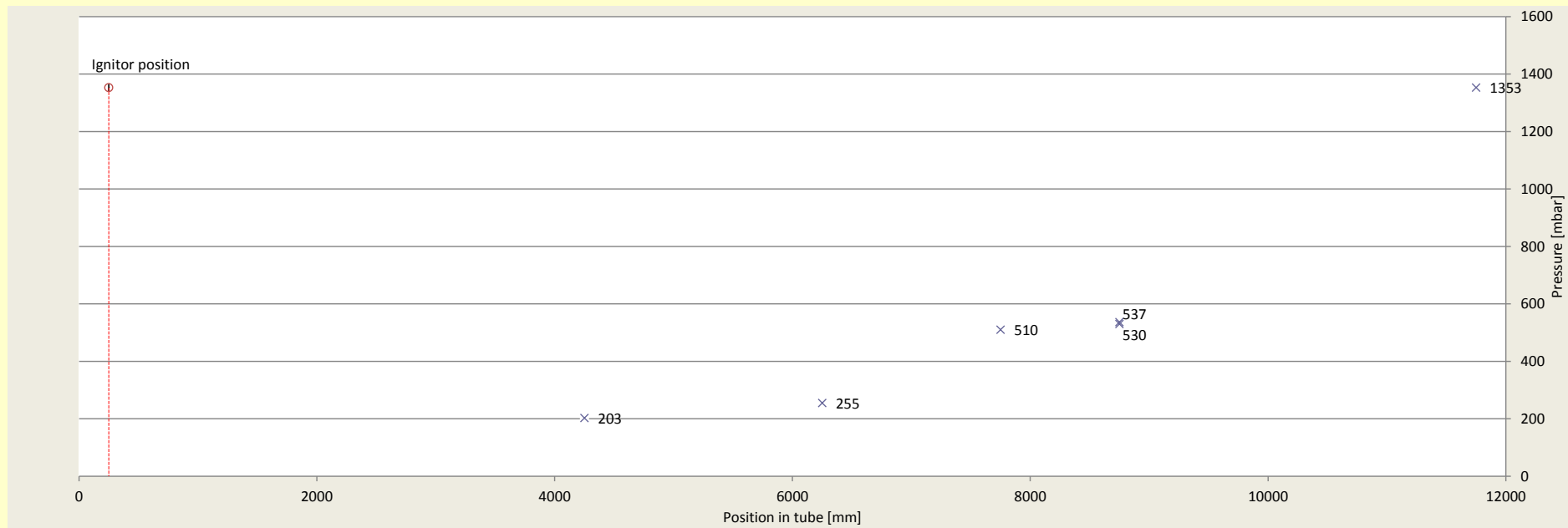
223.9



Location of igniter mm

| Transducer number | Location | Position in tube [mm] | ΔP_{max} [mbar] |
|-------------------|----------|-----------------------|-------------------------|
| KU0 | NS3-6 | 8750 | 537 |
| KU1 | 0 | #N/A | |
| KU2 | 0 | #N/A | |
| KU3 | NS2-3 | 4250 | 203 |
| KU4 | 0 | #N/A | |
| KU5 | NS3-4 | 7750 | 510 |
| KU6 | NS3-1 | 6250 | 255 |
| KU7 | NS4-6 | 11750 | 1353 |
| PB2 | TS3-6 | 8750 | 530 |

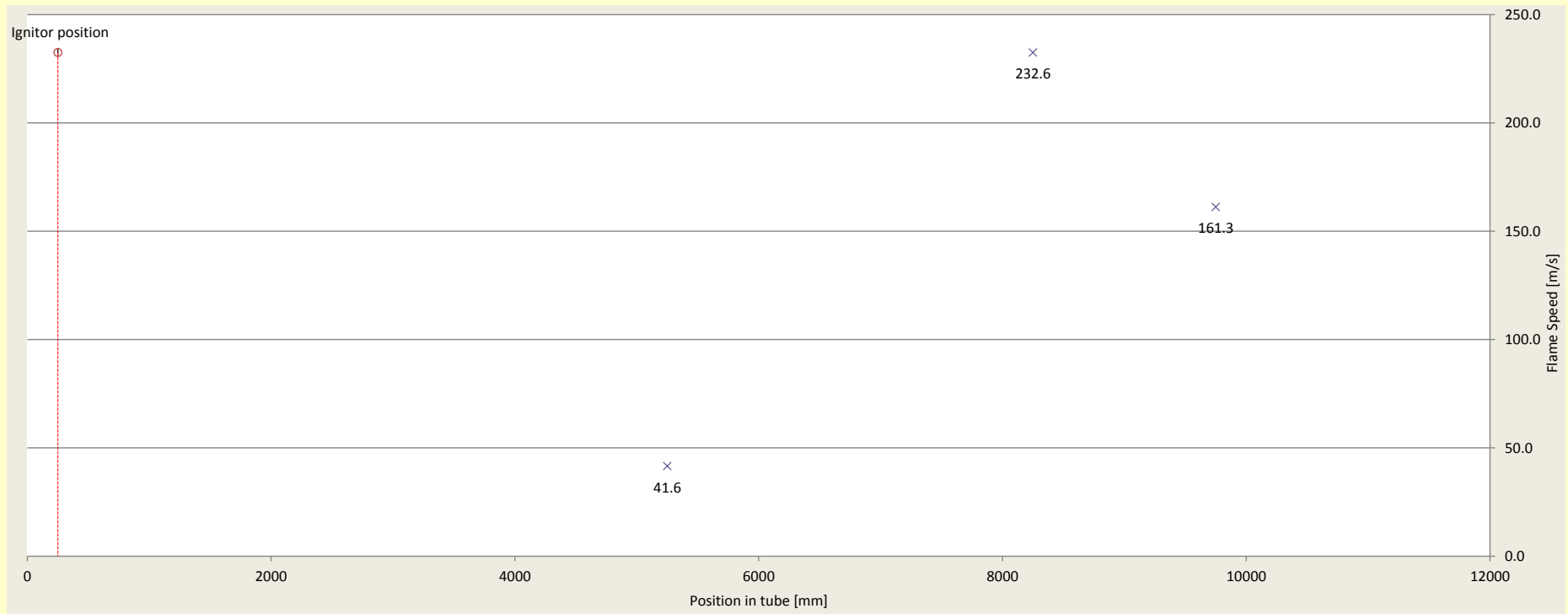
PCB = 530 mbar



Location of igniter mm

Time of ignition seconds

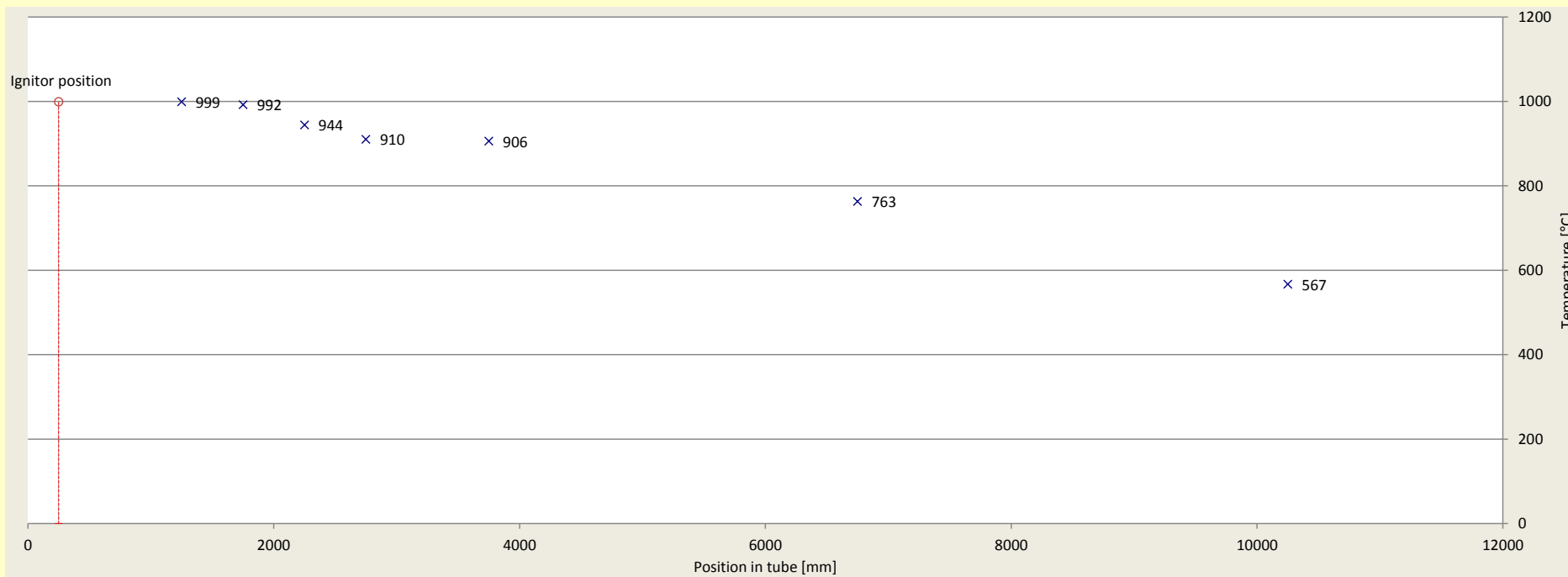
| OP Number | Location label | Position in tube (mm) | Flame arrival time (s) | Average flame speed (m/s) |
|-----------|----------------|-----------------------|------------------------|---------------------------|
| OP0 | NS2-5 | 5250 | 8.5233 | 41.6 |
| OP1 | NS3-5 | 8250 | 8.5362 | 232.6 |
| OP2 | NS4-2 | 9750 | 8.5455 | 161.3 |
| OP3 | NS4-5 | 11250 | NS | |
| OP4 | 0 | #N/A | | |
| OP5 | 0 | #N/A | | |

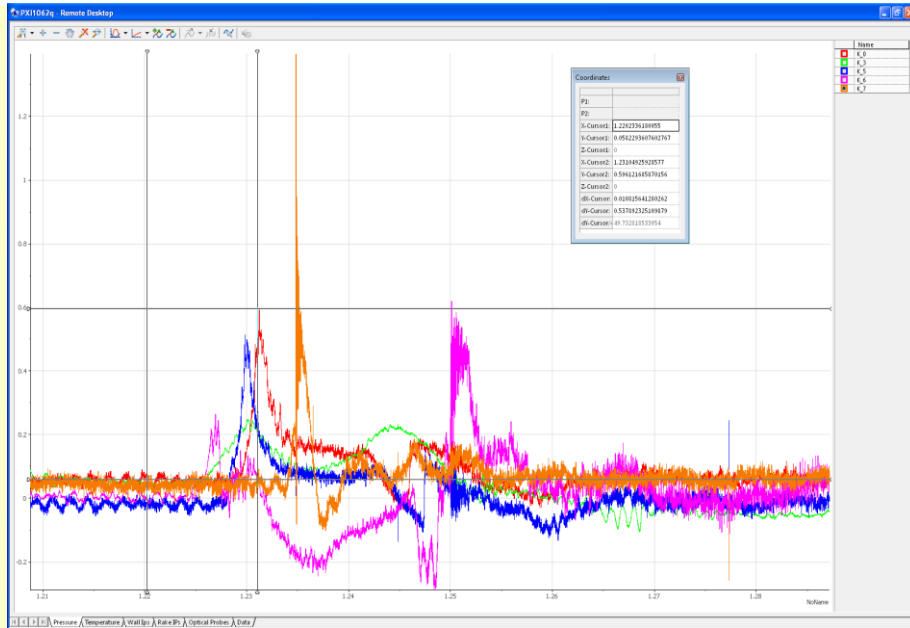


Location of igniter

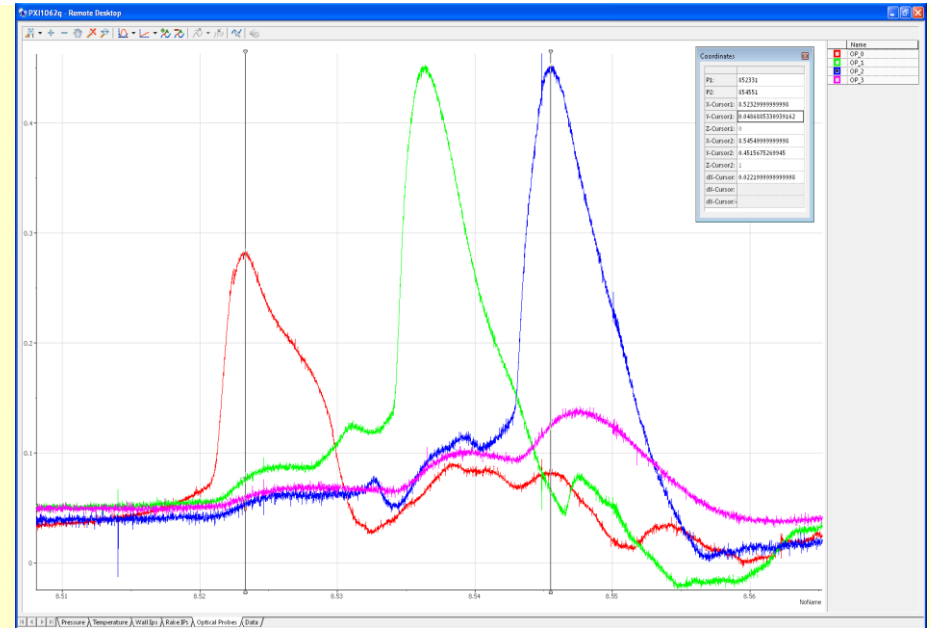
250 mm

| Thermocouple number | Location | Position in tube (mm) | T _{max} (deg C) |
|---------------------|----------|-----------------------|--------------------------|
| TC0 | NS1-3 | 1250 | 999 |
| TC1 | NS1-5 | 2250 | 944 |
| TC2 | NS2-2 | 3750 | 906 |
| TC3 | NS1-4 | 1750 | 992 |
| TC4 | NS1-6 | 2750 | 910 |
| TC5 | Ku6 | #N/A | |
| TC6 | NS3-2 | 6750 | 763 |
| TC15 | NS4-3 | 10250 | 567 |

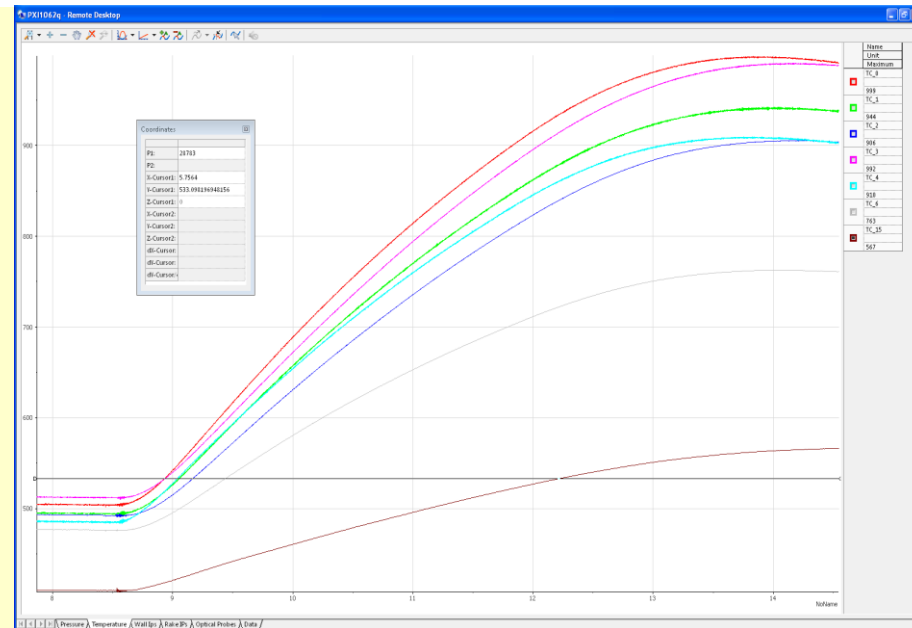
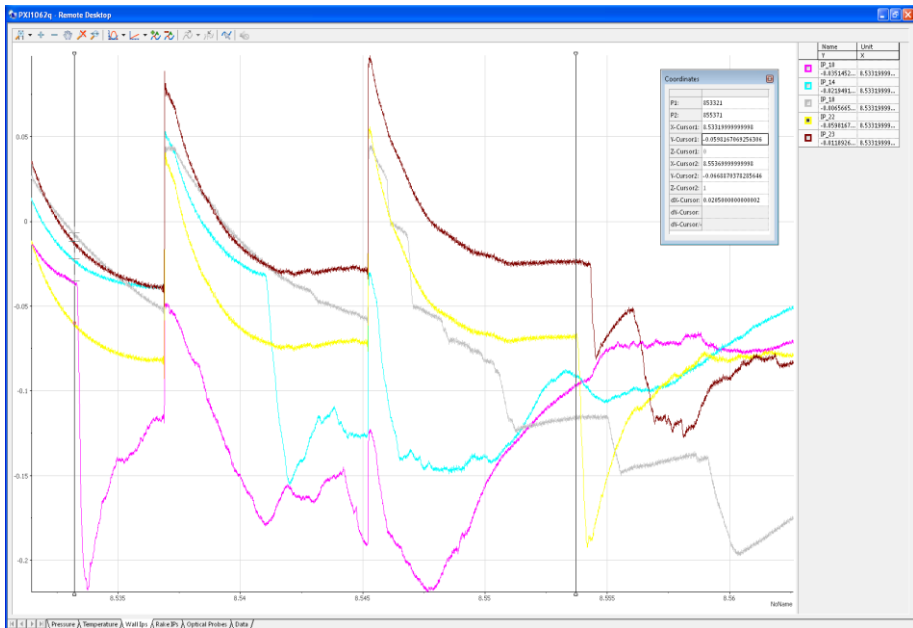




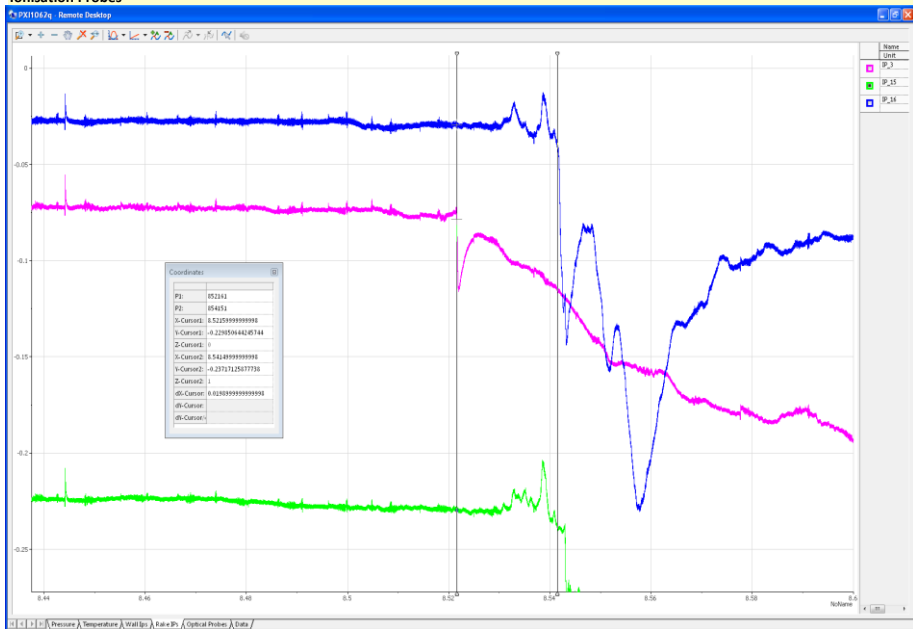
Pressure



Optical Probes



Ionisation Probes



Temperature