

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	IPO	#N/A	#N/A	IP1	#N/A	#N/A	IP2	#N/A	#N/A	IP6	#N/A	#N/A	IP10	#N/A	#N/A	IP14	#N/A	IP18	#N/A	#N/A	IP22	IP23

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	KU0	TC1	OP0	#N/A	TC2	TC3	#N/A	TC4	#N/A	KU3	TC6	KU5	#N/A	OP1	KU6	#N/A	OP2	TC15	#N/A	OP3	KU7

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	#N/A	
R2-2	#N/A	
R2-3	#N/A	
R3-1	IP11	
R3-2	IP12	
R3-3	IP13	
R4-1	IP15	
R4-2	IP16	
R4-3	IP17	
RS-1	#N/A	
RS-2	IP20	
RS-3	#N/A	
KU3	TC7	
KU4	TC9	
KU6	TC13	
pitot	TC11	

Ionisation Probe	Light Blue
Pressure Transducer	Dark Blue
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		PXIe	PXI Slot2/ai7	Flame Presence	Ionisation Probe	Bruce Ewan	TBC	-5 to 5V	60V	100 kHz
IP8		PXIe	PXI Slot6/ai0	Flame Presence	Ionisation Probe	Bruce Ewan	TBC	-5 to 5V	60V	100 kHz
IP9		PXIe	PXI Slot6/ai1	Flame Presence	Ionisation Probe	Bruce Ewan	TBC	-5 to 5V	60V	100 kHz
IP10	FS3-3	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		PXIe	PXI Slot7/ai3	Flame Presence	Ionisation Probe	Bruce Ewan	TBC	-5 to 5V	60V	100 kHz
IP20	RS-2	PXIe	PXI Slot7/ai4	Flame Presence	Ionisation Probe	Bruce Ewan	TBC	-5 to 5V	60V	100 kHz
IP21		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	NS1-6	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		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/ai0	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	NS2-3	PXIe	SC1Mod4/ai3	Gas Temperature (Wall)	K-Type Thermocouple	TC-Direct	1100°C	Conditioned	None	5 kHz
TC4	NS2-5	PXIe	SC1Mod4/ai4	Gas Temperature (Wall)	K-Type Thermocouple	TC-Direct	1100°C	Conditioned	None	5 kHz
TC5		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	KU3	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	KU4	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	KU6	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	NS1-4	PXIe	SC1Mod1/ai0	Pressure	Kulite					100 kHz
KU1		PXIe	SC1Mod1/ai1	Pressure	Kulite					100 kHz
KU2		PXIe	SC1Mod1/ai2	Pressure	XTEH-190M-50BARA			0-100 mV		100 kHz
KU3	NS3-1	PXIe	SC1Mod1/ai3	Pressure	Kulite					100 kHz
KU4		PXIe	SC1Mod1/ai4	Pressure	Kulite					100 kHz
KU5	NS3-3	PXIe	SC1Mod1/ai5	Pressure	Kulite					100 kHz
KU6	NS3-6	PXIe	SC1Mod1/ai6	Pressure	Kulite					100 kHz
KU7	NS4-6	PXIe	SC1Mod1/ai7	Pressure	Kulite					100 kHz
PB1		PXIe	PXI Slot3/ai0	Pressure	113824	PCB	68 bar	0-5 V	20-30 V	1 MHz
PB2		PXIe		Pressure	113825	PCB	68 bar	0-5 V	20-30 V	1 MHz

Date	02 October 2014
Time	15:56
Test Number	21
Mixture Composition	40% CH4/ 60% H2
Ambient Temperature	11 oC
Ambient Pressure	980
Wind Speed	3.6 m/s
Wind direction	SSW
Relative Humidity	84.00%
Equivalence Ratio	~0.85

**General Comments: (weather, rig configuration)**

Weather: Fair with a light breeze

Tube configuration:  
4 x 3m tube sections  
igniter 250mm from beginning of tube section

Third test with congestion in place. Eight (8) rows of congestion in place from central flange (between tube sections 2 and 3).  
Tests on mixture of 40% CH4 and 60% H2 at highest EQR

Pressure transducers and optical probes provided reliable data showing significant increase in overpressure [highest yet seen] and some higher flame speeds which correlated well with data from ionisation probes.

The variation in the apparent flame arrival times at IP3, IP4 and IP5 (3.5 ms) raised questions of the flame speeds immediately downstream based on the sensors from which this is calculated. Flame speed are consistently higher than those measure for test 20 with a lower EQR (0.65)

The pressure pulse shows a sharpening as it travels downstream after passing the congestion. This can also be seen in the development of the pressure pulse upstream from the congestion [K0]. The oscillation seen on the sensors as of yet is not fully understood but is not thought to be related to the natural frequency of the

**Headlines**

Max overpressure  
1670 mbar

Max. flame speed  
451 m/s  
[ionisation probes]

Max. temperature  
1109 °C

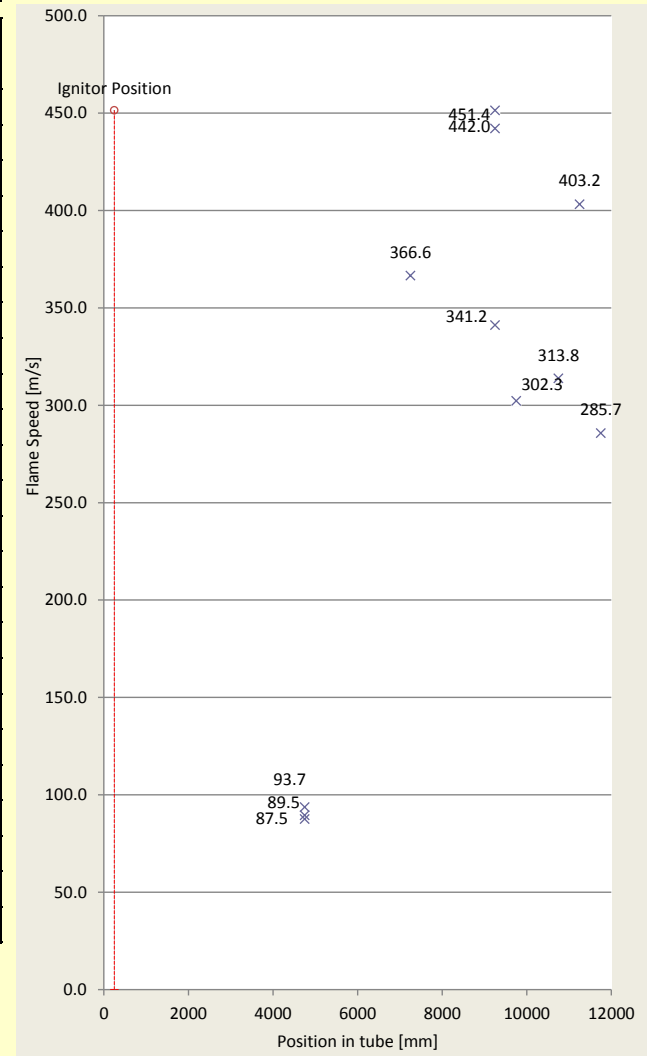
381 m/s  
[optical probes]

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		
IP3	R1-1	Flameion_3	4750	1.4150	87.5
IP4	R1-2	Flameion_4	4750	1.4139	89.5
IP5	R1-3	Flameion_5	4750	1.4116	93.7
IP6	FS2-6	Flameion_6	5750		
IP7	0	Flameion_7	#N/A		
IP8	0	Flameion_8	#N/A		
IP9	0	Flameion_9	#N/A		
IP10	FS3-3	Flameion_10	7250	1.4185	366.6
IP11	R3-1	Flameion_11	7750		
IP12	R3-2	Flameion_12	7750		
IP13	R3-3	Flameion_13	7750		
IP14	FS3-6	Flameion_14	8750		
IP15	R4-1	Flameion_15	9250	1.4250	451.4
IP16	R4-2	Flameion_16	9250	1.4241	442.0
IP17	R4-3	Flameion_17	9250	1.4248	341.2
IP18	FS4-2	Flameion_18	9750	1.4267	302.3
IP19	0	Flameion_19	#N/A		
IP20	R5-2	Flameion_20	10750	1.4289	313.8
IP21	0	Flameion_21	#N/A		
IP22	FS4-5	Flameion_22	11250	1.4305	403.2
IP23	FS4-6	Flameion_23	11750	1.4322	285.7

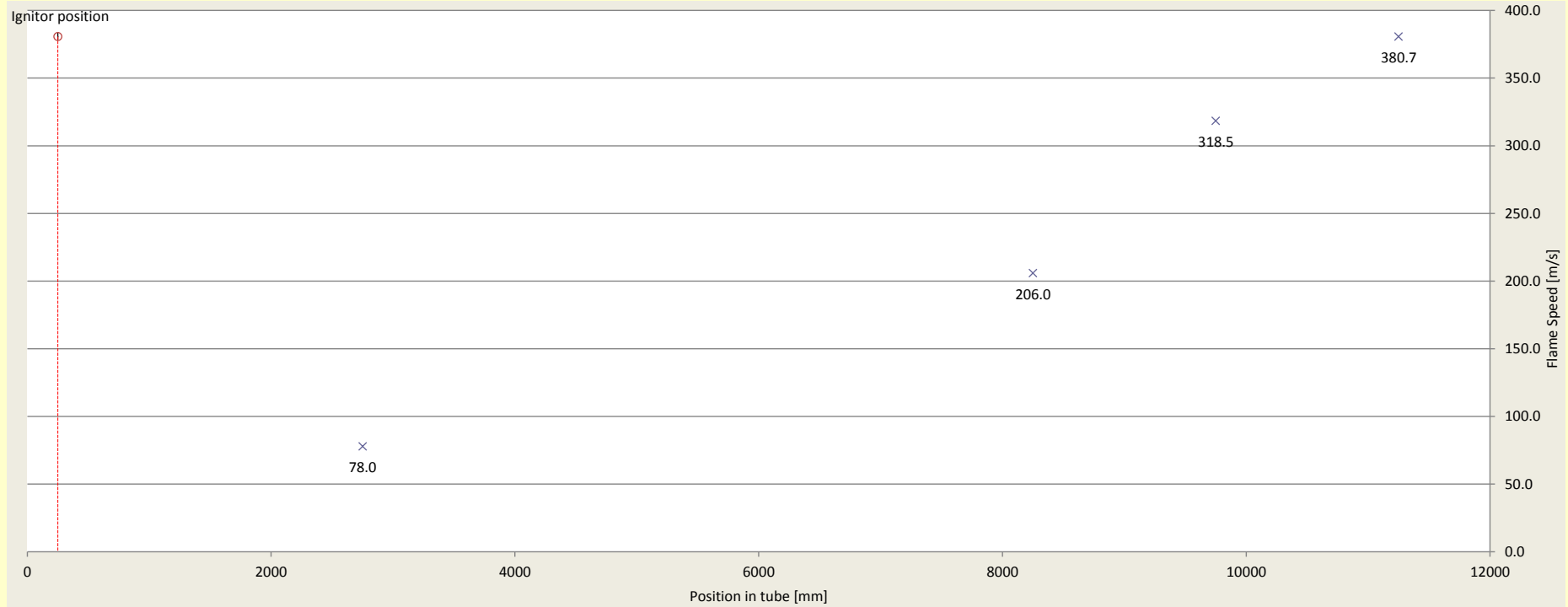
451.4



Location of igniter  mm

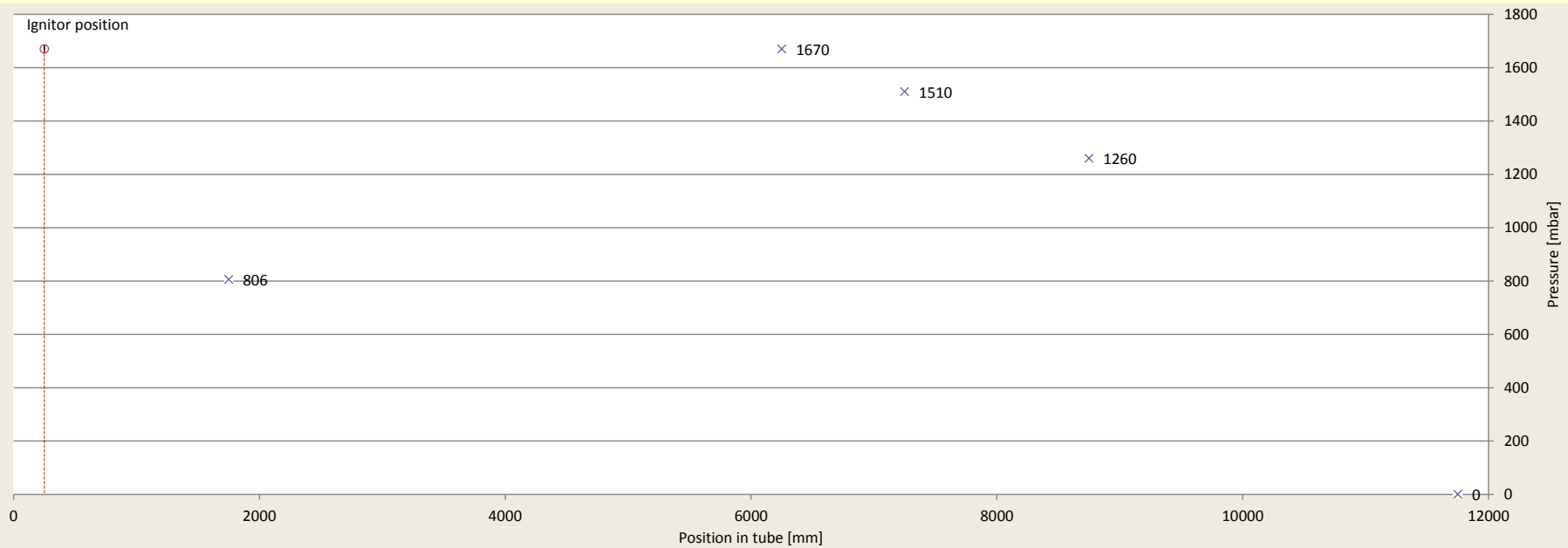
Time of ignition  seconds

OP Number	Location label	Position in tube (mm)	Flame arrival time (s)	Average flame speed (m/s)
OP0	NS1-6	2750	1.39568	78.0
OP1	NS3-5	8250	1.42238	206.0
OP2	NS4-2	9750	1.42709	318.5
OP3	NS4-5	11250	1.43103	380.7
OP4	0	#N/A		
OP5	0	#N/A		



Location of igniter  mm

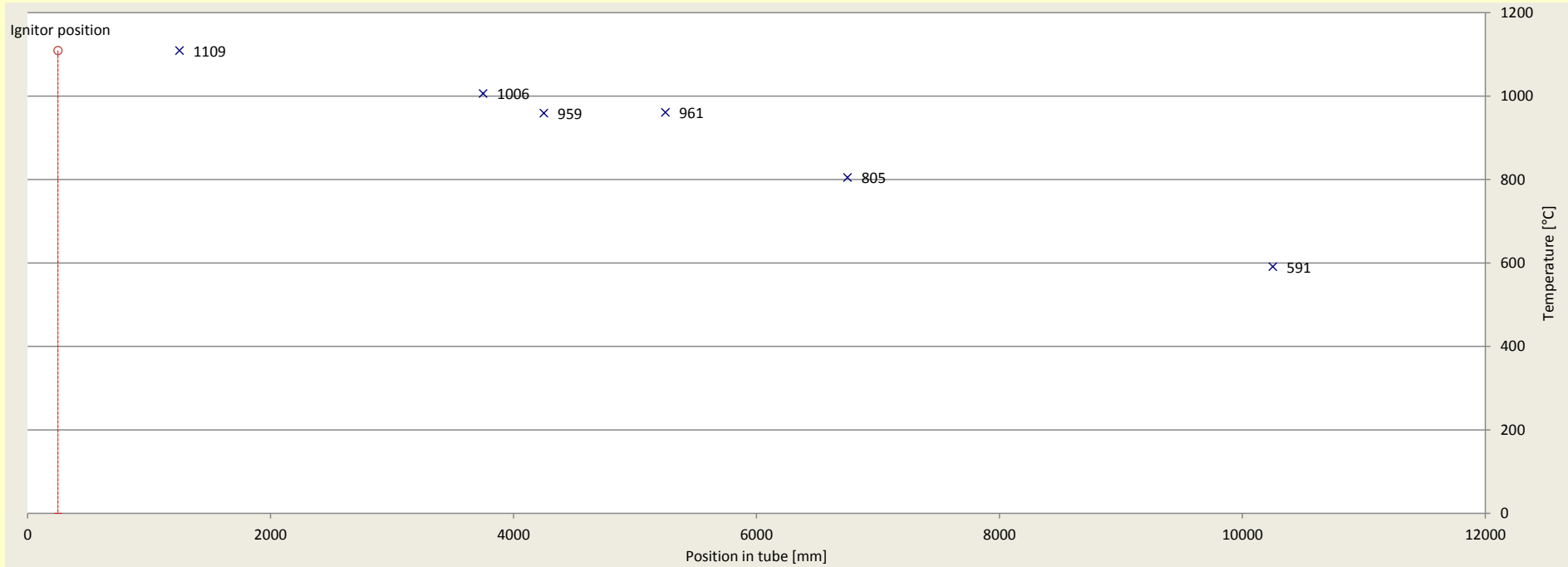
Transducer number	Location	Position in tube [mm]	$\Delta P_{max}$ [mbar]
KU0	NS1-4	1750	806
KU1	0	#N/A	
KU2	0	#N/A	
KU3	NS3-1	6250	1670
KU4	0	#N/A	
KU5	NS3-3	7250	1510
KU6	NS3-6	8750	1260
KU7	NS4-6	11750	0

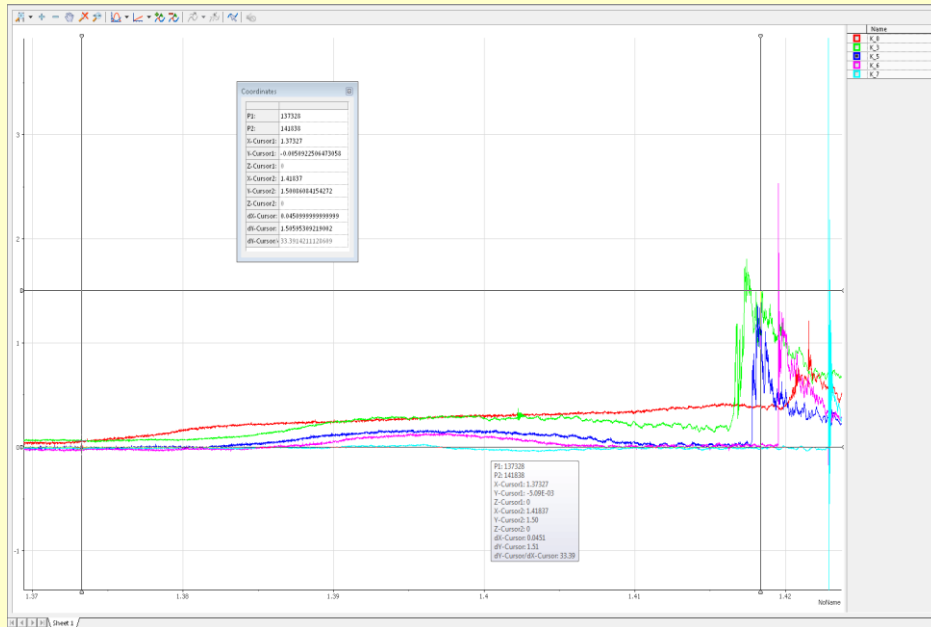


Location of igniter

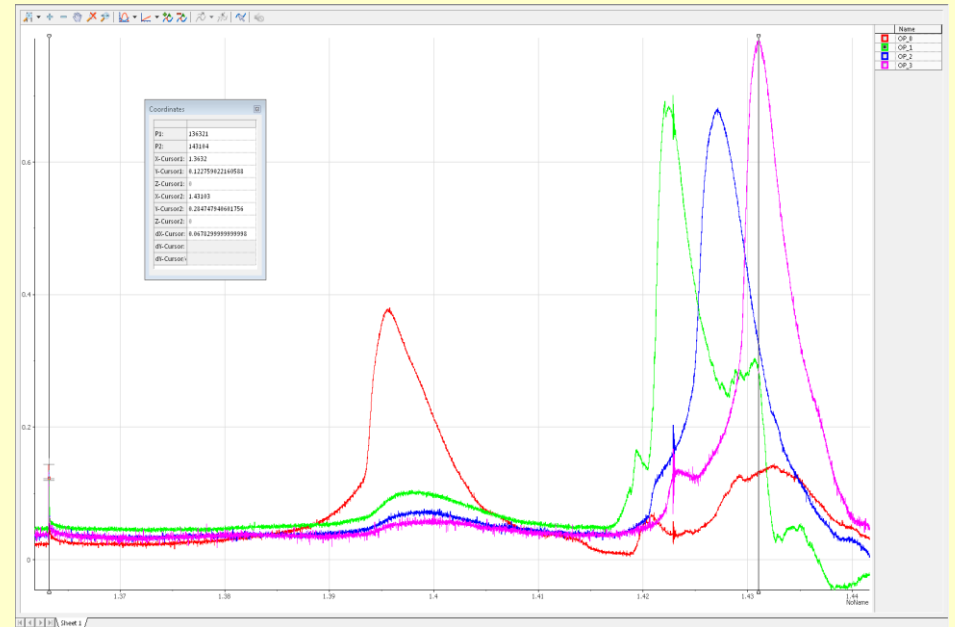
250 mm

Thermocouple number	Location	Position in tube (mm)	T <sub>max</sub> (deg C)
TC0	NS1-3	1250	1109
TC1	NS1-5	2250	
TC2	NS2-2	3750	1006
TC3	NS2-3	4250	959
TC4	NS2-5	5250	961
TC5	0	#N/A	
TC6	NS3-2	6750	805
TC15	NS4-3	10250	591

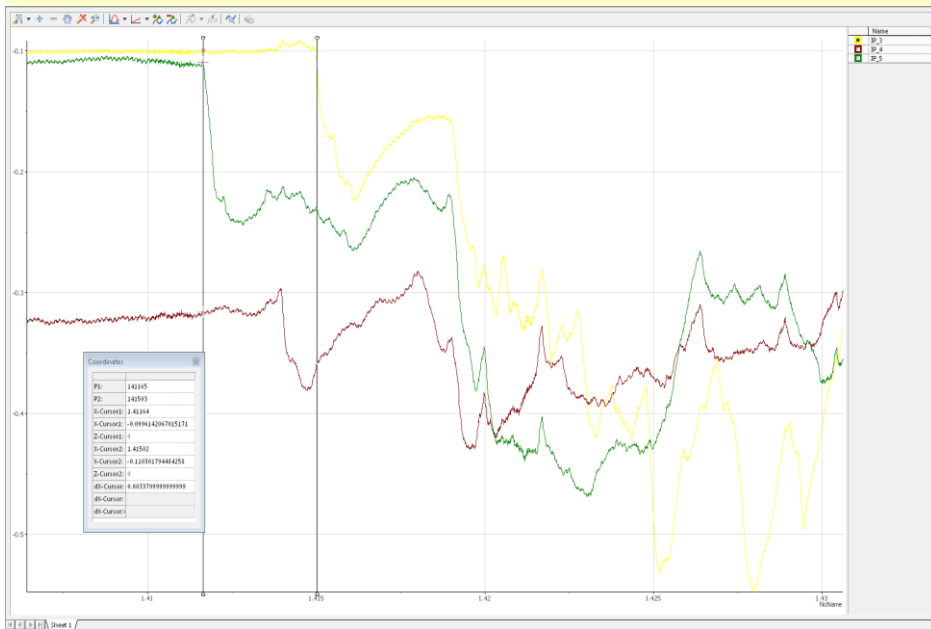




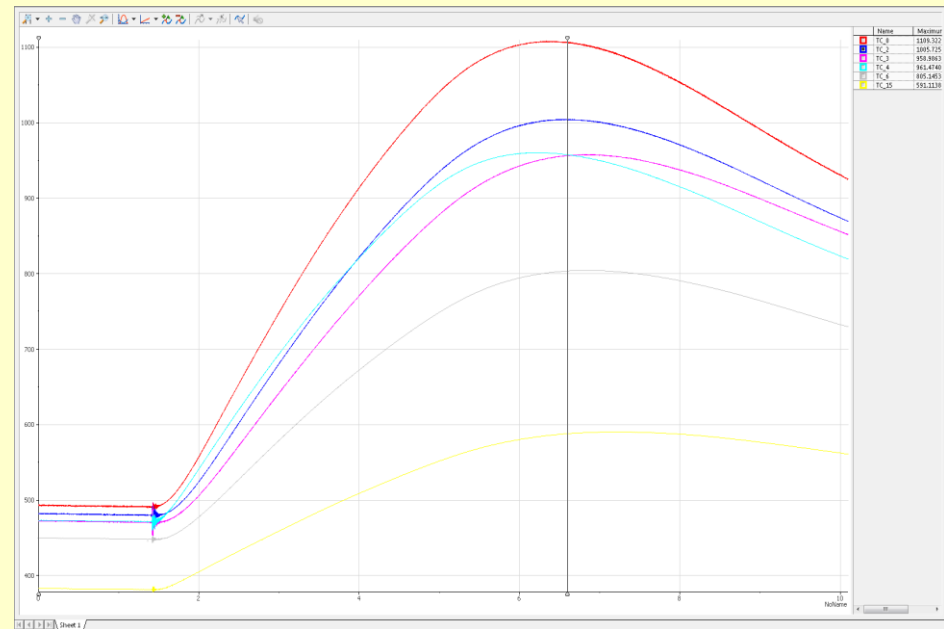
Pressure



Optical Probes



**Ionisation Probes**



**Temperature**