

Date	28 June 2018
Time	12:04:41
Test Number	HRSG Test 19
Mixture Composition	100% H2
Ambient Temperature	22 °C
Ambient Pressure	978 mbar
Wind Speed	2 m/s
Wind direction	NE
Relative Humidity	55.00%
Mass Flow	<input type="text"/> kg/s
Equivalence Ratio	0.51

General Comments: (weather, rig configuration)

Weather: Sunny and hot, light breeze

Rig configuration: 4 x 3m circular duct; expansion section and HRSG attached. End Plate attached. Igniter 258mm from beginning of 2nd circular duct section

Engine Speed: 40%; 11,800 rpm

Repeat test on 100 % hydrogen at an EQR 0.51

The test gave a mild combustion event and most sensors provided an identifiable response.

Maximum overpressure of 522 mbar was seen on KU10 near the end plate.

Ionisation Probes

Max. flame speed
 m/s

Max. temperature
 °C

Initial Temperature
 °C

Location of Max. Flame Speed

sensor	IP1
label	HR2-L5L
distance	14745 mm

Location of Max. Temperature

sensor	TC2
label	CD2-R3
distance	4258 mm

Ionisation Rakes

Max. flame speed
 m/s

Location of Max. Flame Speed

sensor	RA3
label	HR4-R3M
distance	17575 mm

Optical Probes

Max. flame speed
 m/s

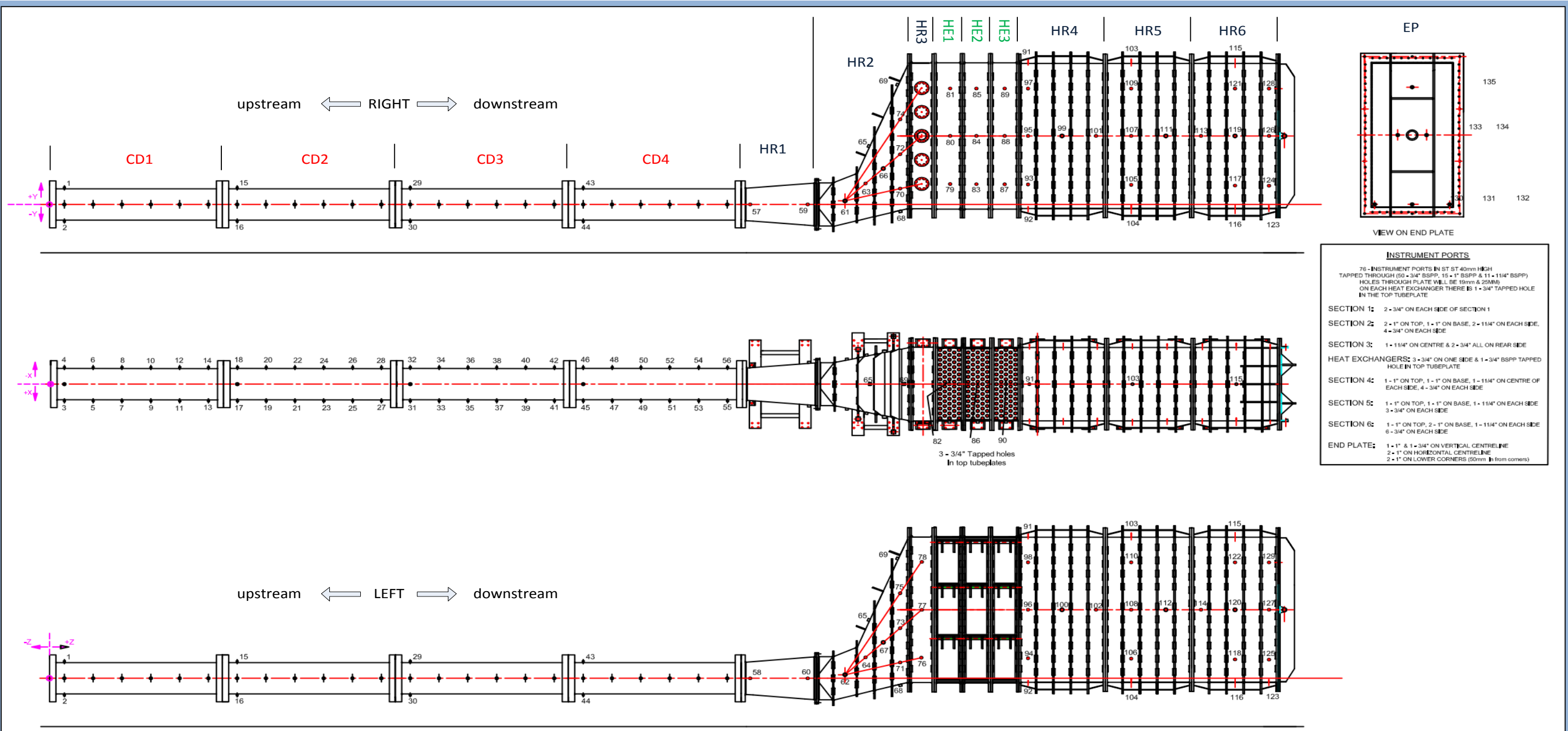
Location of Max. Flame Speed

sensor	OP1
label	CD4-R6
distance	11758 mm

Max overpressure
 mbar

Location of Max. Overpressure

sensor	KU10
label	HR6-L5L
distance	21165 mm



INSTRUMENT PORTS

76 - INSTRUMENT PORTS IN ST 40mm HIGH TAPPED THROUGH (50 - 3/4" BSPP, 15 - 1" BSPP & 11 - 1/4" BSPP) HOLES THROUGH PLATE WILL BE 10mm & 25mm ON EACH HEAT EXCHANGER THERE IS 1 - 3/4" TAPPED HOLE IN THE TOP TUBEPLATE

SECTION 1: 2 - 3/4" ON EACH SIDE OF SECTION 1

SECTION 2: 2 - 1" ON TOP, 1 - 1" ON BASE, 2 - 1/4" ON EACH SIDE, 4 - 3/4" ON EACH SIDE

SECTION 3: 1 - 1/4" ON CENTRE & 2 - 3/4" ALL ON REAR SIDE

HEAT EXCHANGERS: 3 - 3/4" ON ONE SIDE & 1 - 3/4" BSPP TAPPED HOLE IN TOP TUBEPLATE

SECTION 4: 1 - 1" ON TOP, 1 - 1" ON BASE, 1 - 1/4" ON CENTRE OF EACH SIDE, 4 - 3/4" ON EACH SIDE

SECTION 5: 1 - 1" ON TOP, 1 - 1" ON BASE, 1 - 1/4" ON EACH SIDE, 3 - 3/4" ON EACH SIDE

SECTION 6: 1 - 1" ON TOP, 2 - 1" ON BASE, 1 - 1/4" ON EACH SIDE, 6 - 3/4" ON EACH SIDE

END PLATE: 1 - 1" & 1 - 3/4" ON VERTICAL CENTRELINE, 2 - 1" ON HORIZONTAL CENTRELINE, 2 - 1" ON LOWER CORNERS (50mm from corners)

Naming Convention

Section Identifier i.e. HE, HR, CD or EP	H R 1 - R 1 U	Vertical position in section (sides only) i.e. U, M or L. Absence of letter denotes centreline
Section Number (1-6) Numbered from downstream to upstream	Side i.e. R, L, T or B	Longitudinal position in section (numbered from 1)

Key

CD Circular duct	U Upper
HR HRSG	M Middle
HE Heat Exchanger	L Lower
EP End Plate	R Right Side (when viewed downstream from engine)
	L Left Side
	T Top
	B Bottom

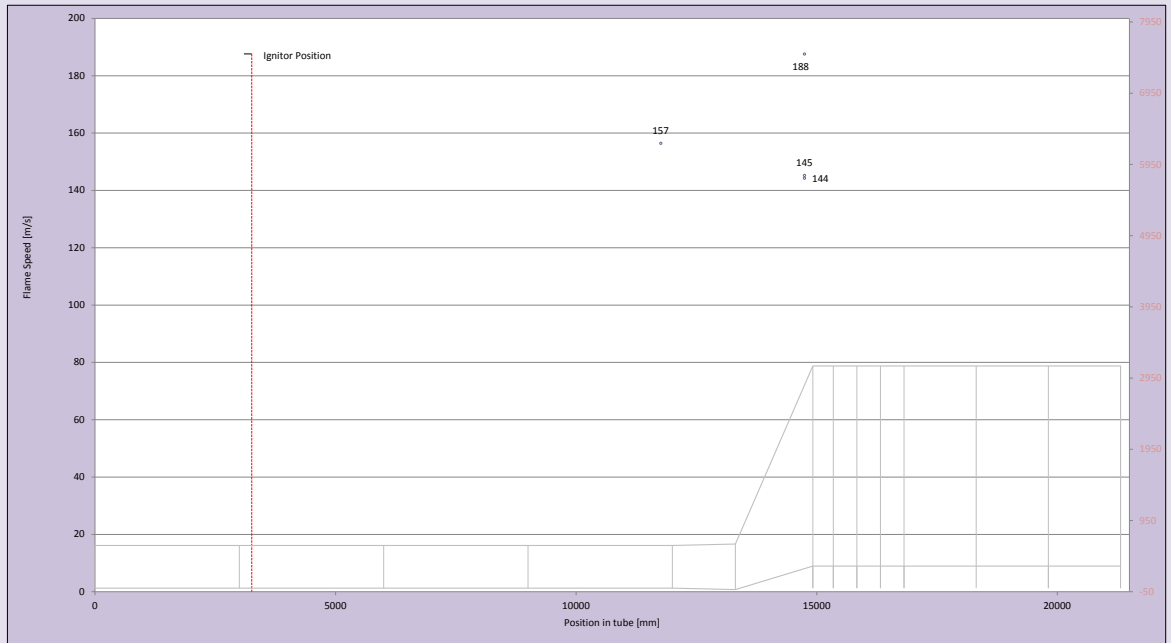
There are 13 sections on the rig

- 4 circular duct sections (CD1 to CD4)
- 6 HRSG sections (HR1 to HR6)
- 3 heat exchanger sections (HE1 to HE3) located between HR3 and HR4

Location of igniter 3258 mm Time of ignition 18.99813 seconds

IP Number	Location label	Data Name	Position in tube (mm)	Flame arrival time (s)	Avg Flame speed from last sensor (m/s)
IP0	CD4-L6	sation probe 0	11758	19.05244	157
IP1	HR2-L5L	sation probe 1	14745	19.06836	188
IP2	HR2-L5M	sation probe 2	14745	19.07720	145
IP3	HR2-L5U	sation probe 3	14745	19.07772	144
IP4	HR3-R1L	sation probe 4	15140	19.07165	
IP5	HR3-R1LM	sation probe 5	15140	19.07262	
IP6	HR3-R1M	sation probe 6	15140	19.07501	
IP7	HR3-R1U	sation probe 7	15140	19.07427	
IP8	HR3-L1U	sation probe 8	15140	19.07201	
IP9	HE2-R1M	sation probe 9	16090	19.07157	
IP10	HR4-L1L	sation probe 10	16985	19.07202	
IP11	HR4-L1M	sation probe 11	16985	19.07202	
IP12	HR4-L1U	sation probe 12	16985	19.07354	
IP13	HR4-R1U	sation probe 13	16985	19.07437	
IP14	HR4-R3U	sation probe 14	17575	19.07437	
IP15	HR4-L5L	sation probe 15	18165	19.07437	
IP16	HR4-L5M	sation probe 16	18165	19.06845	
IP17	HR4-L5U	sation probe 17	18165	19.07501	
IP18	HR4-R5M	sation probe 18	18165	19.07458	
IP19	HR5-L2L	sation probe 19	18775	19.07455	
IP20	HR5-L2M	sation probe 20	18775	19.07458	
IP21	HR5-L2U	sation probe 21	18775	NW	
IP22	HR5-R2U	sation probe 22	18775	ND	
IP23	HR6-L1M	sation probe 23	19985	ND	

KEY: ND - not detected - sensor working but flame too weak to be picked up
 NW - not working - sensor not working

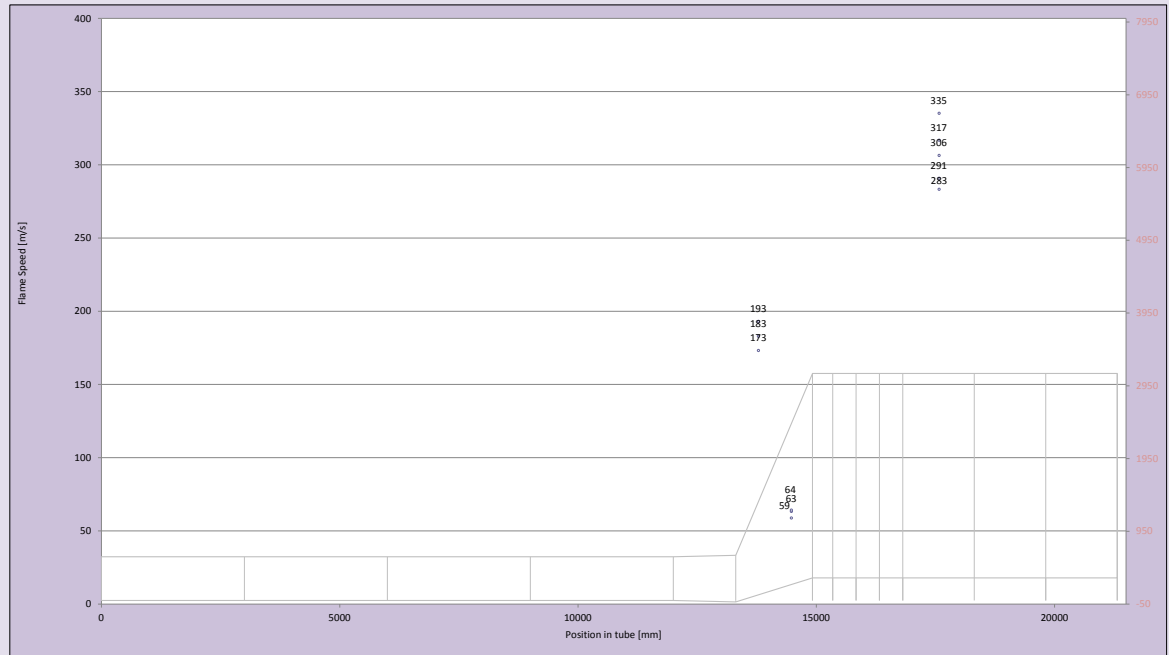


Location of igniter 3258 mm

Time of ignition 18.99813 seconds

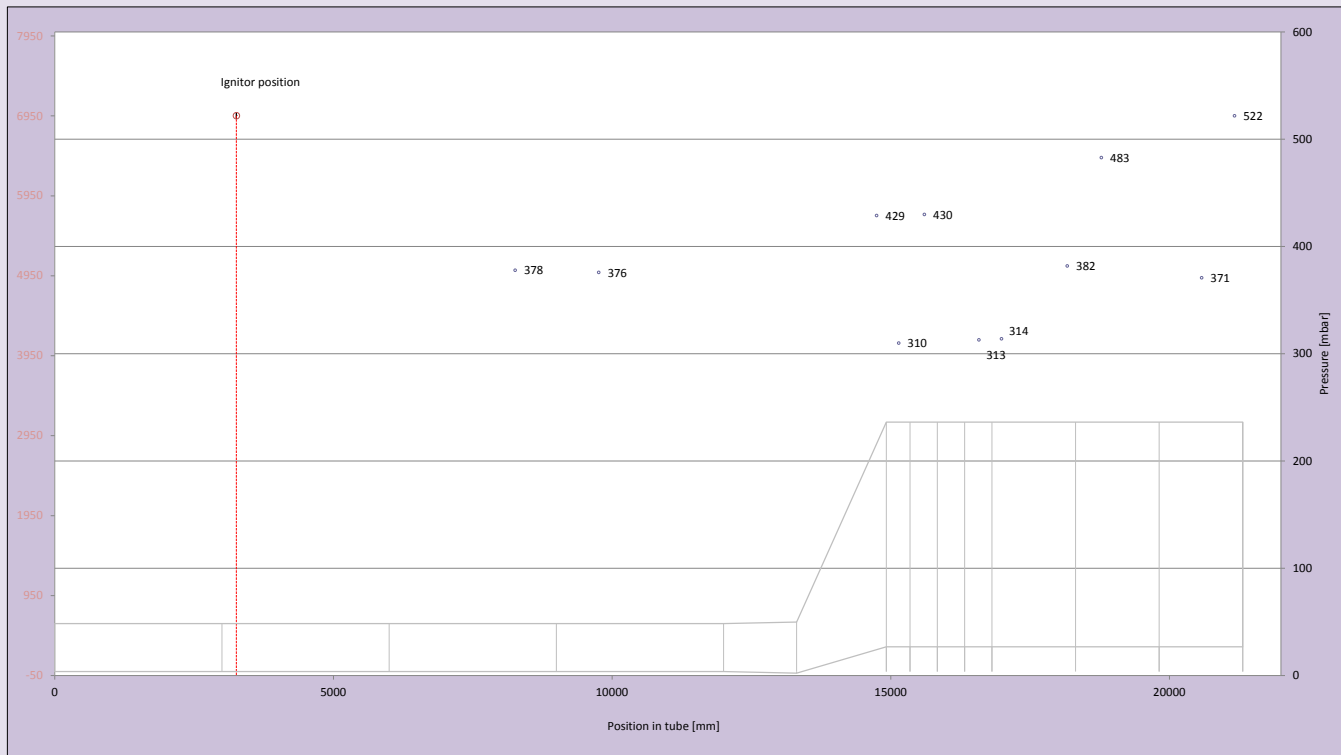
Rake Number	IP Number	Location label	Data Name	Position in tube (mm)	Flame arrival time (s)	Avg Flame speed from last sensor (m/s)
RA1	IP24	HR2-R2M	IP24	13785	19.0589	173
RA1	IP25	HR2-R2M	IP25	13785	19.0526	193
RA1	IP26	HR2-R2M	IP26	13785	19.0557	183
RA2	IP27	HR2-R4M	IP27	14475	19.0698	63
RA2	IP28	HR2-R4M	IP28	14475	19.0696	64
RA2	IP29	HR2-R4M	IP29	14475	19.0706	59
RA3	IP30	HR4-R3M	IP30	17575	19.0804	291
RA3	IP31	HR4-R3M	IP31	17575	19.0807	283
RA3	IP32	HR4-R3M	IP32	17575	19.0790	335
RA4	IP33	HR4-R3L	IP33	17575	19.0796	317
RA4	IP34	HR4-R3L	IP34	17575	19.0799	306
RA4	IP35	HR4-R3L	IP35	17575	NW	

KEY: ND - not detected - sensor working but flame too weak to be picked up
 NW - not working - sensor not working



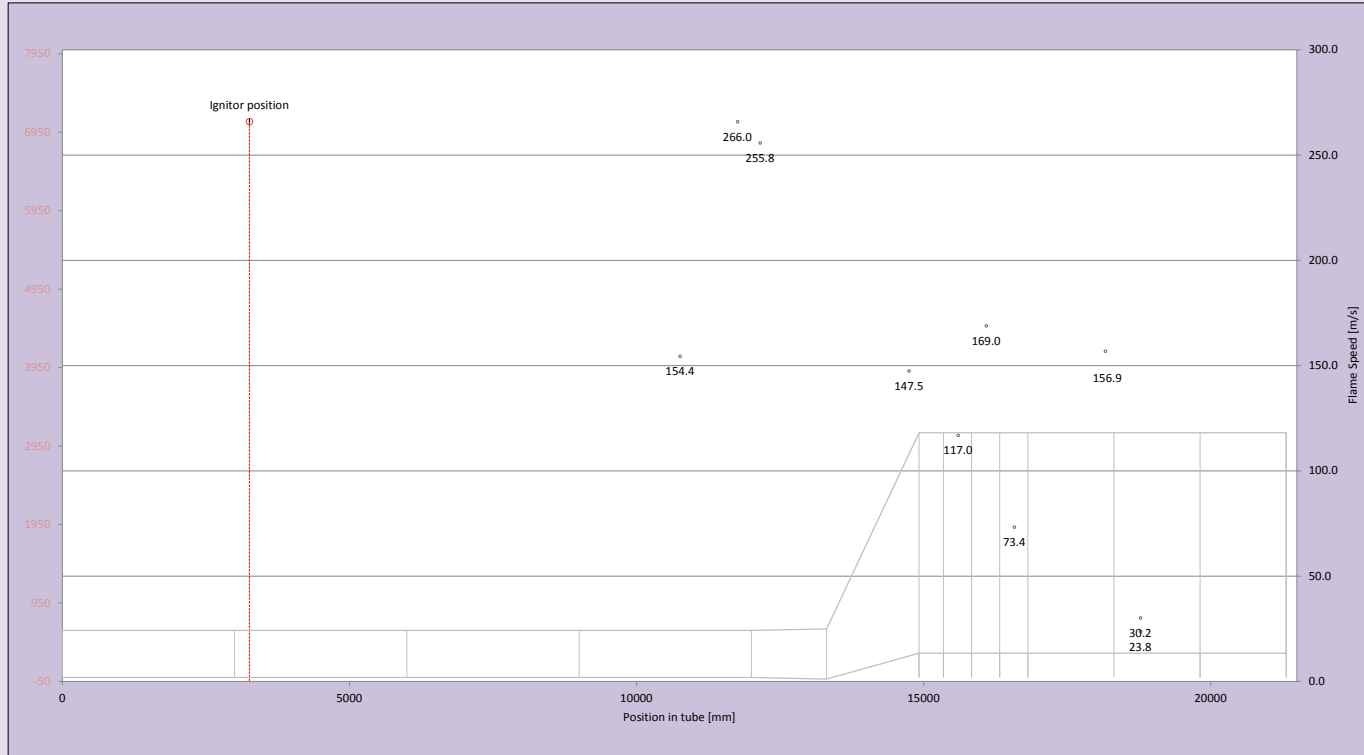
Location of igniter mm

Transducer number	Location	Position in tube [mm]	P_{max} [mbar]	Time P_{max} [sec]
KU0	CD3-R5	8258	378	19.1062
KU1	CD4-R2	9758	376	19.1034
KU2	HR2-T5	14745	429	19.0768
KU3	HR3-L1L	15140	310	19.0993
KU4	HE1-R1U	15600	430	19.0761
KU5	HE3-R1L	16580	313	19.0958
KU6	HR4-R1L	16985	314	19.0940
KU7	HR4-R5U	18165	382	19.0811
KU8	HR5-R2L	18775	483	19.0892
KU9	HR6-R3L	20575	371	19.0853
KU10	HR6-L5L	21165	522	19.0861



Location of igniter mm Time of ignitio seconds

OP Number	Location label	Position in tube (mm)	Flame arrival time (s)	Average flame speed (m/s)
OP0	CD4-L4	10758	19.0467	154.4
OP1	CD4-R6	11758	19.0504	266.0
OP2	HR1-R1	12152	19.0520	255.8
OP3	HR2-R5M	14745	19.0696	147.5
OP4	HE1-T1	15600	19.0769	117.0
OP5	HE2-T1	16090	19.0775	169.0
OP6	HE3-T1	16580	19.0842	73.4
OP7	HR4-T1	16985	19.0763	-51.1
OP8	HR4-R1M	16985	19.0773	-58.7
OP9	HR4-R5L	18165	19.0848	156.9
OP10	HR5-T2	18775	19.1050	30.2
OP11	HR5-R2M	18775	19.1105	23.8



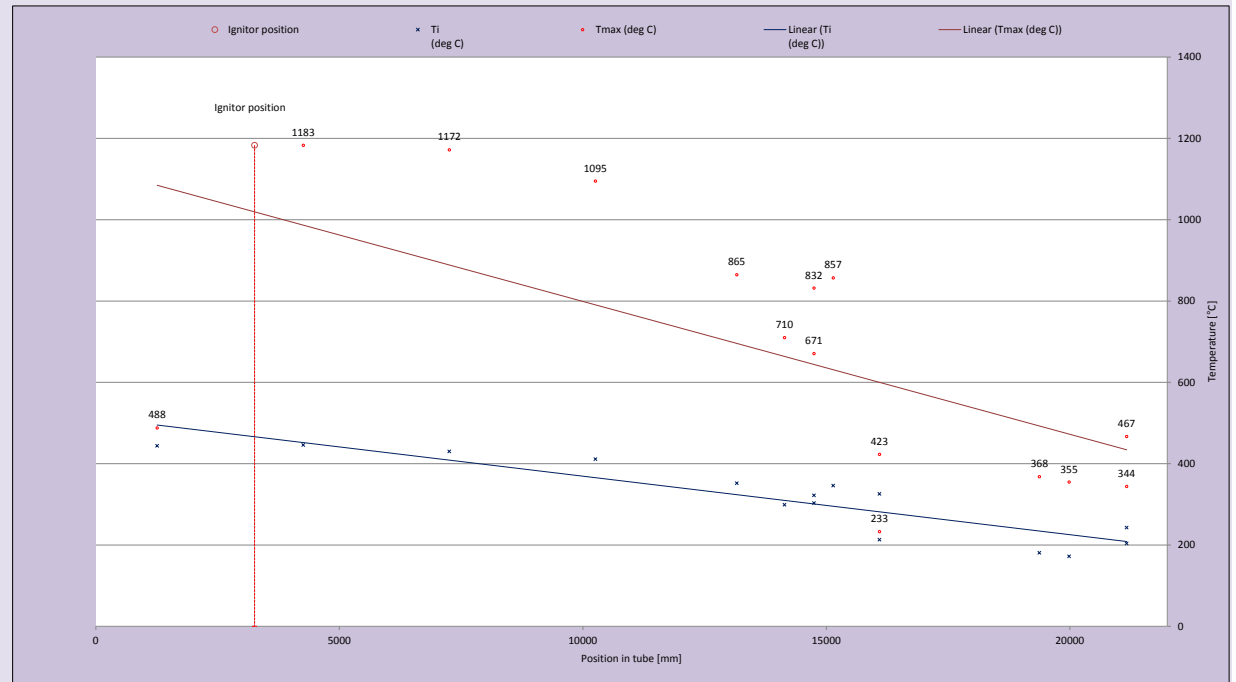
Location of igniter 3258 mm Time of ignition 18.99813 seconds

Thermocouple number	Location	Position in tube (mm)	Flame arrival time (s)	Average flame speed (m/s)	T _{max} (deg C)	T _i (deg C)
TC0	CD1-R3	1258			488	444
TC2	CD2-R3	4258	19.031	30	1183	446
TC4	CD3-R3	7258	19.037	500	1172	430
TC6	CD4-R3	10258	19.042	600	1095	411
TC8	HR1-R2	13160	19.072	97	865	352
TC16	HR2-R3M	14140	19.073	980	710	299
TC17	HR2-R5L	14745	19.078	121	832	322
TC18	HR2-R5U	14745	19.088	40	671	303
TC19	HR3-L1M	15140	19.093	79	857	346
TC20	HE2-R1L	16090	19.117	40	423	326
TC21	HE2-R1U	16090	19.108	63	233	213
TC22	HR5-R4M	19375	19.164	59	368	181
TC23	HR6-R1M	19985	19.217	12	355	172
TC24	HR6-R5L	21165	19.356	8	344	204
TC25	HR6-R5U	21165	19.357	8	467	243

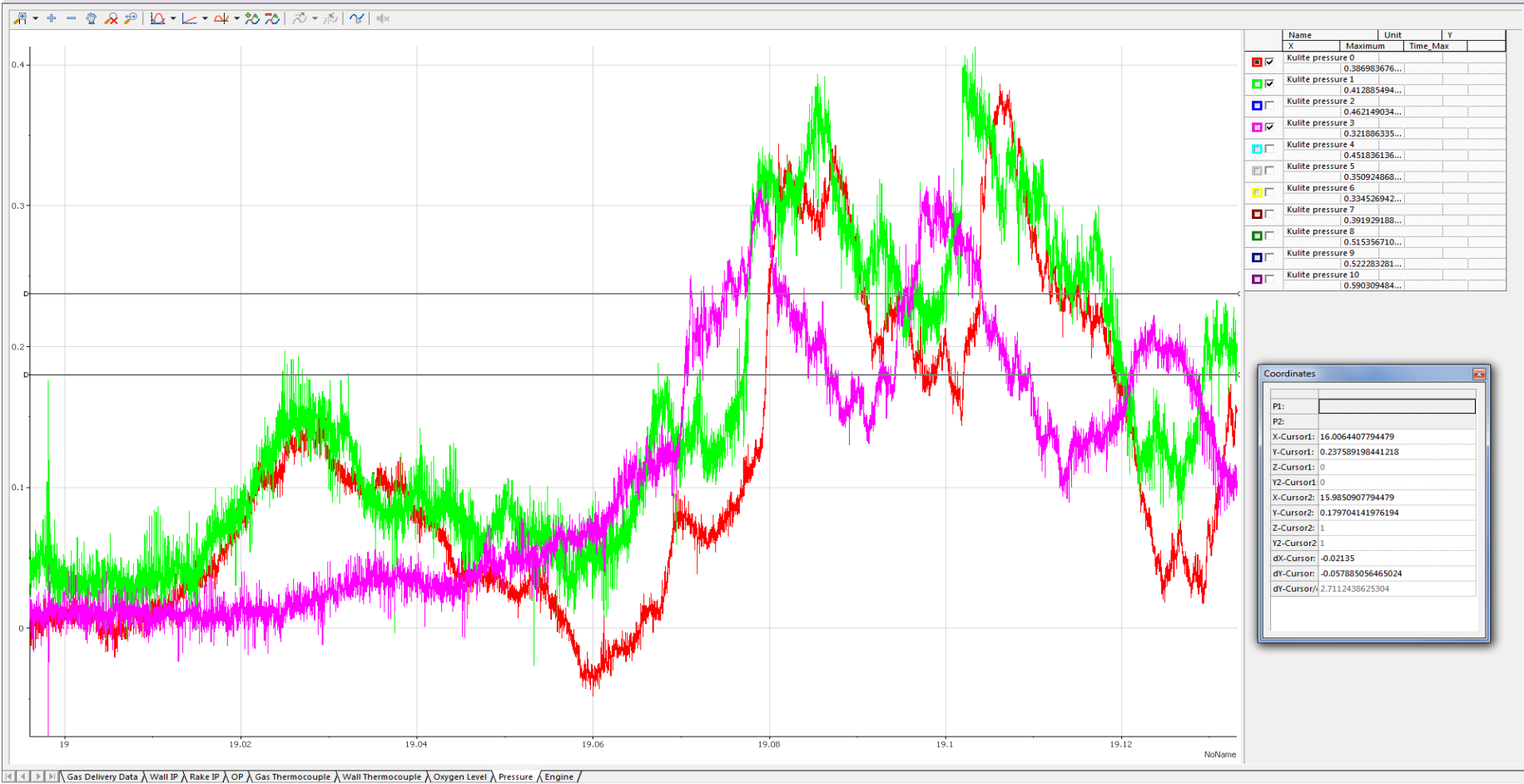
surface thermocouples [not plotted]

TC	Location	Position in tube (mm)	T _{max} (deg C)	T _i (deg C)
TC1	CD1-T2	1508	98	93
TC3	CD2-T2	4508	76	72
TC5	CD3-T2	7508	26	25
TC7	CD4-T2	10508	51	42

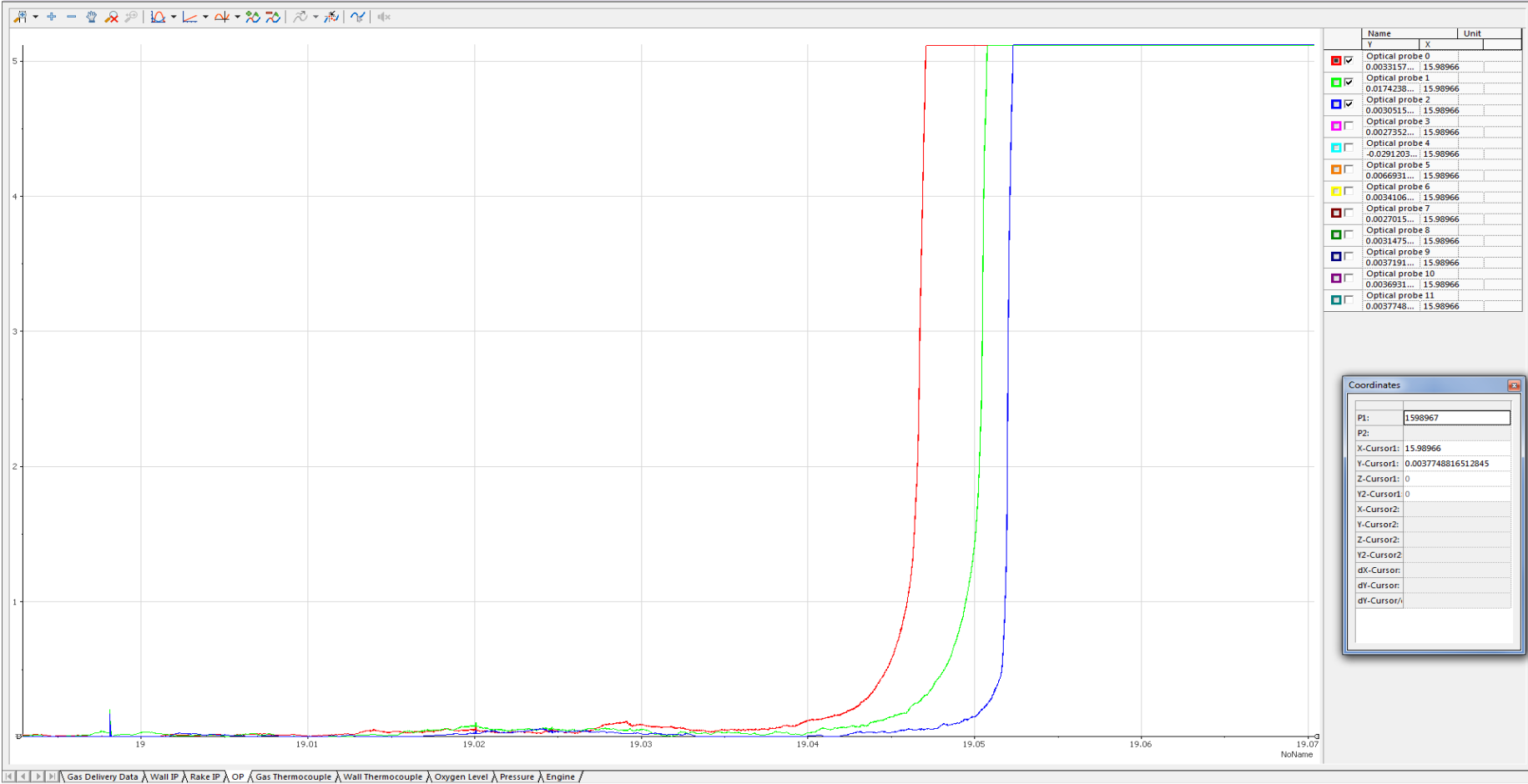
The flame arrival time is measured as the time when the thermocouple registers a 10 °C increase from its baseline value.



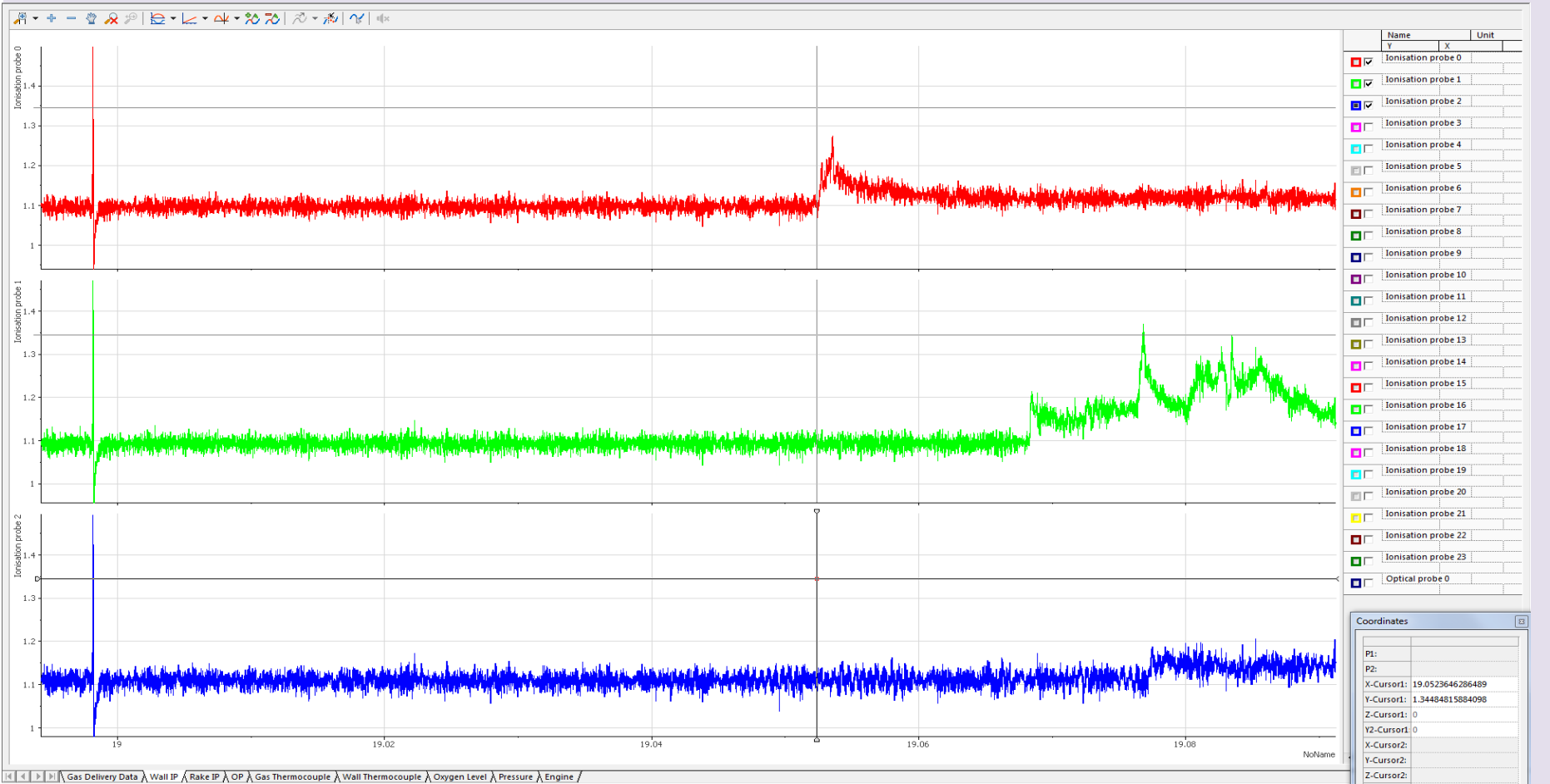
Pressure



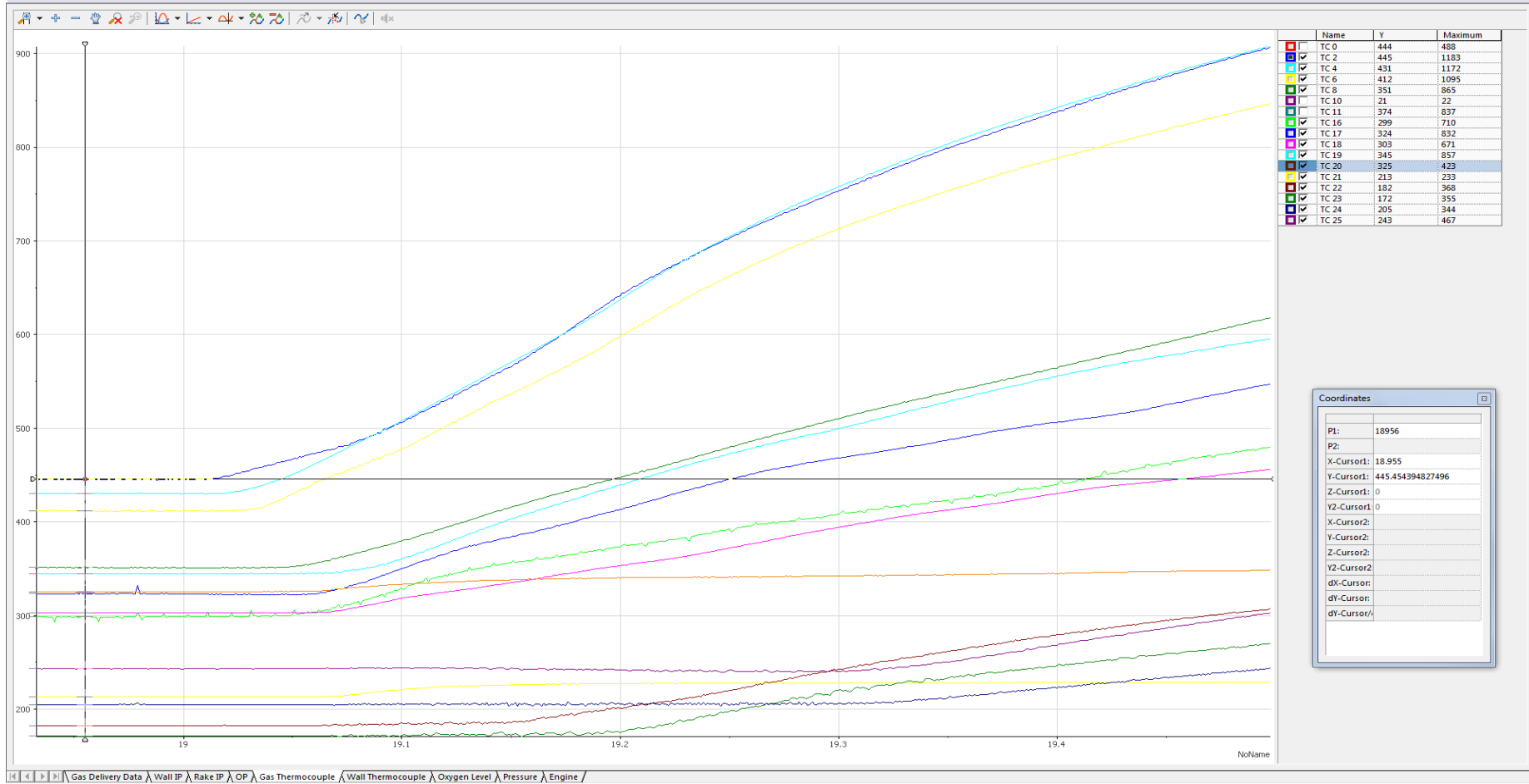
Optical Probes



Ionisation Probes



Temperature



Sensor	OLD DESIGNATION	NEW DESIGNATION	Section	Section Number	Side	Horizontal Location	Vertical Location	PORT REF	SIZE	"X"	"Y"	"Z"
-	NS1-1	CD1-R1	CD	1	R	1		3	3/4" BSPP	298	0	258
-	NS1-2	CD1-R2	CD	1	R	2		5	3/4" BSPP	298	0	758
TC0	NS1-3	CD1-R3	CD	1	R	3		7	3/4" BSPP	298	0	1258
-	NS1-4	CD1-R4	CD	1	R	4		9	3/4" BSPP	298	0	1758
-	NS1-5	CD1-R5	CD	1	R	5		11	3/4" BSPP	298	0	2258
-	NS1-6	CD1-R6	CD	1	R	6		13	3/4" BSPP	298	0	2758
-	NS2-1	CD2-R1	CD	2	R	1		17	3/4" BSPP	298	0	3258
-	NS2-2	CD2-R2	CD	2	R	2		19	3/4" BSPP	298	0	3758
TC2	NS2-3	CD2-R3	CD	2	R	3		21	3/4" BSPP	298	0	4258
-	NS2-4	CD2-R4	CD	2	R	4		23	3/4" BSPP	298	0	4758
-	NS2-5	CD2-R5	CD	2	R	5		25	3/4" BSPP	298	0	5258
-	NS2-6	CD2-R6	CD	2	R	6		27	3/4" BSPP	298	0	5758
-	NS3-1	CD3-R1	CD	3	R	1		31	3/4" BSPP	298	0	6258
-	NS3-2	CD3-R2	CD	3	R	2		33	3/4" BSPP	298	0	6758
TC4	NS3-3	CD3-R3	CD	3	R	3		35	3/4" BSPP	298	0	7258
-	NS3-4	CD3-R4	CD	3	R	4		37	3/4" BSPP	298	0	7758
KU0	NS3-5	CD3-R5	CD	3	R	5		39	3/4" BSPP	298	0	8258
-	NS3-6	CD3-R6	CD	3	R	6		41	3/4" BSPP	298	0	8758
-	NS4-1	CD4-R1	CD	4	R	1		45	3/4" BSPP	298	0	9258
KU1	NS4-2	CD4-R2	CD	4	R	2		47	3/4" BSPP	298	0	9758
TC6	NS4-3	CD4-R3	CD	4	R	3		49	3/4" BSPP	298	0	10258
-	NS4-4	CD4-R4	CD	4	R	4		51	3/4" BSPP	298	0	10758
-	NS4-5	CD4-R5	CD	4	R	5		53	3/4" BSPP	298	0	11258
OP1	NS4-6	CD4-R6	CD	4	R	6		55	3/4" BSPP	298	0	11758
OP2		HR1-R1	HR	1	R	1		57	3/4" BSPP	308	0	12152
TC8		HR1-R2	HR	1	R	2		59	3/4" BSPP	393	0	13160
RA1		HR2-R2M	HR	2	R	2	M	61	11/4" BSPP	448	70	13785
TC16		HR2-R3M	HR	2	R	3	M	63	3/4" BSPP	528	410	14140
RA2		HR2-R4M	HR	2	R	4	M	66	11/4" BSPP	598	700	14475
TC17		HR2-R5L	HR	2	R	5	L	70	3/4" BSPP	662	310	14745
OP3		HR2-R5M	HR	2	R	5	M	72	3/4" BSPP	662	975	14745
TC18		HR2-R5U	HR	2	R	5	U	74	3/4" BSPP	662	1660	14745
IP4		HR3-R1L	HR	3	R	1	L	136	3/4" BSPP	700	400	15140
IP5		HR3-R1LM	HR	3	R	1	LM	137	3/4" BSPP	700	868	15140
IP6		HR3-R1M	HR	3	R	1	M	138	3/4" BSPP	700	1335	15140
-		HR3-R1UM	HR	3	R	1	UM	139	3/4" BSPP	700	1802	15140
IP7		HR3-R1U	HR	3	R	1	U	140	3/4" BSPP	700	2270	15140
-		HE1-R1L	HE	1	R	1	L	79	3/4" BSPP	700	400	15600
-		HE1-R1M	HE	1	R	1	M	80	3/4" BSPP	700	1335	15600
KU4		HE1-R1U	HE	1	R	1	U	81	3/4" BSPP	700	2270	15600
TC20		HE2-R1L	HE	2	R	1	L	83	3/4" BSPP	700	400	16090
IP9		HE2-R1M	HE	2	R	1	M	84	3/4" BSPP	700	1335	16090
TC21		HE2-R1U	HE	2	R	1	U	85	3/4" BSPP	700	2270	16090
KU5		HE3-R1L	HE	3	R	1	L	87	3/4" BSPP	700	400	16580
-		HE3-R1M	HE	3	R	1	M	88	3/4" BSPP	700	1335	16580
-		HE3-R1U	HE	3	R	1	U	89	3/4" BSPP	700	2270	16580
KU6		HR4-R1L	HR	4	R	1	L	93	3/4" BSPP	700	400	16985
OP8		HR4-R1M	HR	4	R	1	M	95	3/4" BSPP	700	1335	16985
IP13		HR4-R1U	HR	4	R	1	U	97	3/4" BSPP	700	2270	16985
RA3		HR4-R3M	HR	4	R	3	M	99	11/4" BSPP	700	1335	17575
RA4		HR4-R3L	HR	4	R	3	L	141	11/4" BSPP	700	400	17575
IP14		HR4-R3U	HR	4	R	3	U	142	3/4" BSPP	700	2270	17575
IP18		HR4-R5M	HR	4	R	5	M	101	3/4" BSPP	700	1335	18165
OP9		HR4-R5L	HR	4	R	5	L	145	3/4" BSPP	700	400	18165
KU7		HR4-R5U	HR	4	R	5	U	146	3/4" BSPP	700	2270	18165
-		HR5-R1M	HR	5	R	1	M	NA	SURFACE	700	1200	18455
KU8		HR5-R2L	HR	5	R	2	L	105	3/4" BSPP	700	400	18775
OP11		HR5-R2M	HR	5	R	2	M	107	3/4" BSPP	700	1335	18775
IP22		HR5-R2U	HR	5	R	2	U	109	3/4" BSPP	700	2270	18775
TC22		HR5-R4M	HR	5	R	4	M	111	11/4" BSPP	700	1335	19375

Sensor	OLD DESIGNATION	NEW DESIGNATION	Section	Section Number	Side	Horizontal Location	Vertical Location	PORT REF	SIZE	"X"	"Y"	"Z"
TC23		HR6-R1M	HR	6	R	1	M	113	3/4" BSPP	700	1335	19985
KU9		HR6-R3L	HR	6	R	3	L	117	3/4" BSPP	700	400	20575
-		HR6-R3M	HR	6	R	3	M	119	1 1/4" BSPP	700	1335	20575
-		HR6-R3U	HR	6	R	3	U	121	3/4" BSPP	700	2270	20575
TC24		HR6-R5L	HR	6	R	5	L	124	3/4" BSPP	700	400	21165
-		HR6-R5M	HR	6	R	5	M	126	3/4" BSPP	700	1335	21165
TC25		HR6-R5U	HR	6	R	5	U	128	3/4" BSPP	700	2270	21165

