Date	26 June 2018
Time	14:46:00
Test Number	HRSG Test 18
Mixture Composition	100% H2
Ambient Temperature	22 °C
Ambient Pressure	980 mbar
Wind Speed	2 m/s
Wind direction	E
Relative Humidity	40.00%
Mass Flow	9.6900 kg/s
Equivalence Ratio	0.47

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

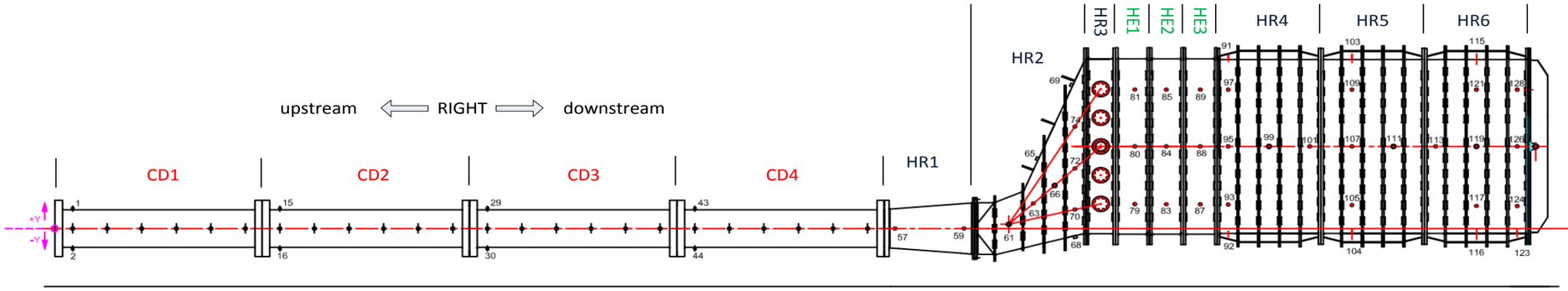
Repeat test on 100 % hydrogen at an EQR 0.47

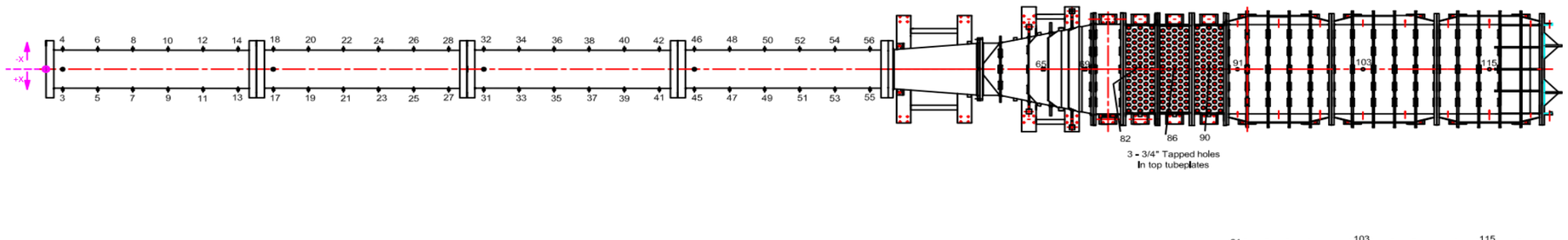
The test gave a mild combustion event and most sensors provided an identifiable response.

Maximum overpressure of 322 mbar was seen on KU10 near the end plate.

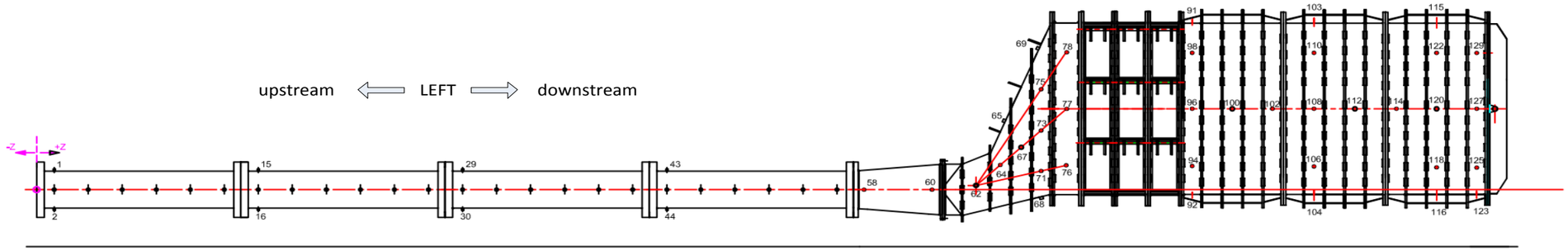
High Speed Video captured in expansion section (colour) and from end plate (black and white) at 3000 fps. Good images from end plate but not clear in expansion section.

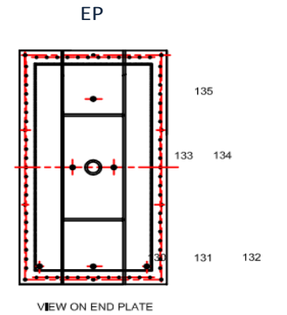
						Ionisation Probes			Ionisation Rakes			Optical Probes			
Max overpressure			Max. temperature			Max. flame speed			Max. flame speed			Max. flame speed			
322	mbar		1116	°C		148	m/s		0	m/s		233	m/s		
			Initial Temperature												
			0	°C											
Location of Max. Overpressure			Location of Max. Temperature			Location of Max. Flame Speed			Location of Max. Flame Speed			Location of Max. Flame Speed			
sensor	KU10		sensor	TC4		sensor	IP0		sensor	RA1		sensor	OP1		
label	HR6-L5L		label	CD3-R3		label	CD4-L6		label	HR2-R2M		label	CD4-R6		
distance	21165	mm	distance	7258	mm	distance	11758	mm	distance	13785	mm	distance	11758	mm	





3 - 3/4" Tapped holes
In top tubeplates





VIEW ON END PLATE

INSTRUMENT PORTS

76 - INSTRUMENT PORTS IN ST ST 40mm HIGH
TAPPED THROUGH (50 - 3/4" BSPP, 15 - 1" BSPP & 11 - 11/4" BSPP)
HOLES THROUGH PLATE WILL BE 19mm & 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 - 11/4" ON EACH SIDE, 4 - 3/4" ON EACH SIDE
SECTION 3:	1 - 11/4" 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 - 11/4" ON CENTRE OF EACH SIDE, 4 - 3/4" ON EACH SIDE
SECTION 5:	1 - 1" ON TOP, 1 - 1" ON BASE, 1 - 11/4" ON EACH SIDE 3 - 3/4" ON EACH SIDE
SECTION 6:	1 - 1" ON TOP, 2 - 1" ON BASE, 1 - 11/4" 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 in from corners)

Naming Convention

Section Identifier
i.e. HE, HR, CD or EP

H R 1 - R 1 U

Section Number (1-6)
Numbered from downstream to upstream

Side
i.e. R, L, T or B

Vertical position in section (sides only) i.e. U, M or L.
Absence of letter denotes centreline

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

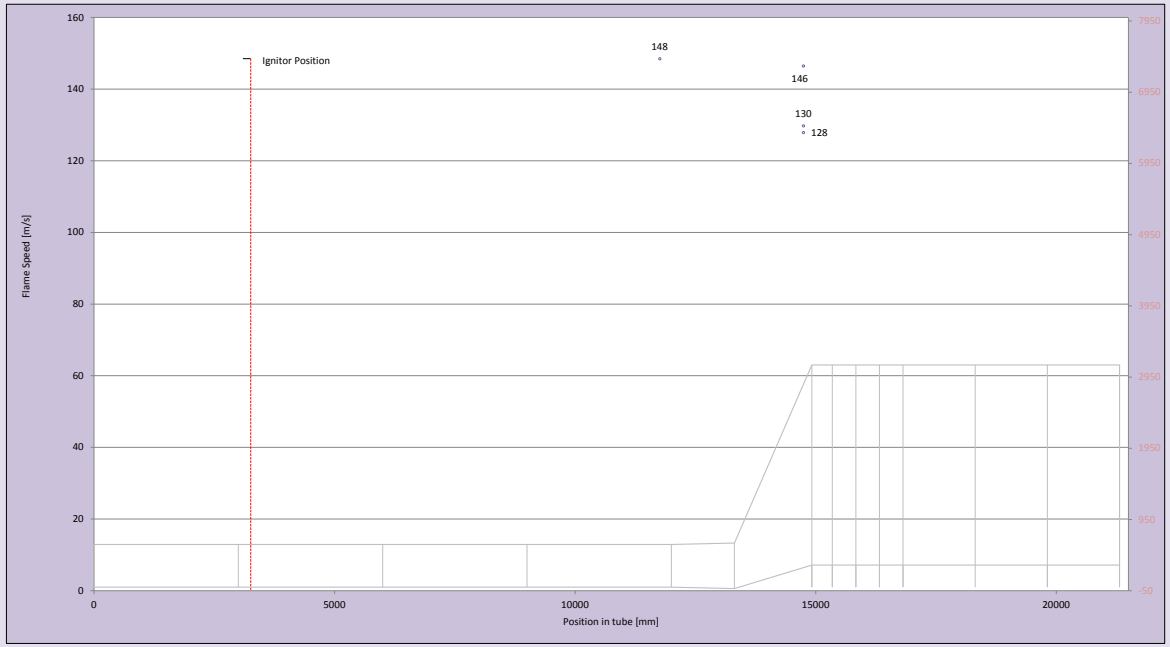
There are 13 sections on the rig

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** 15.84986 seconds

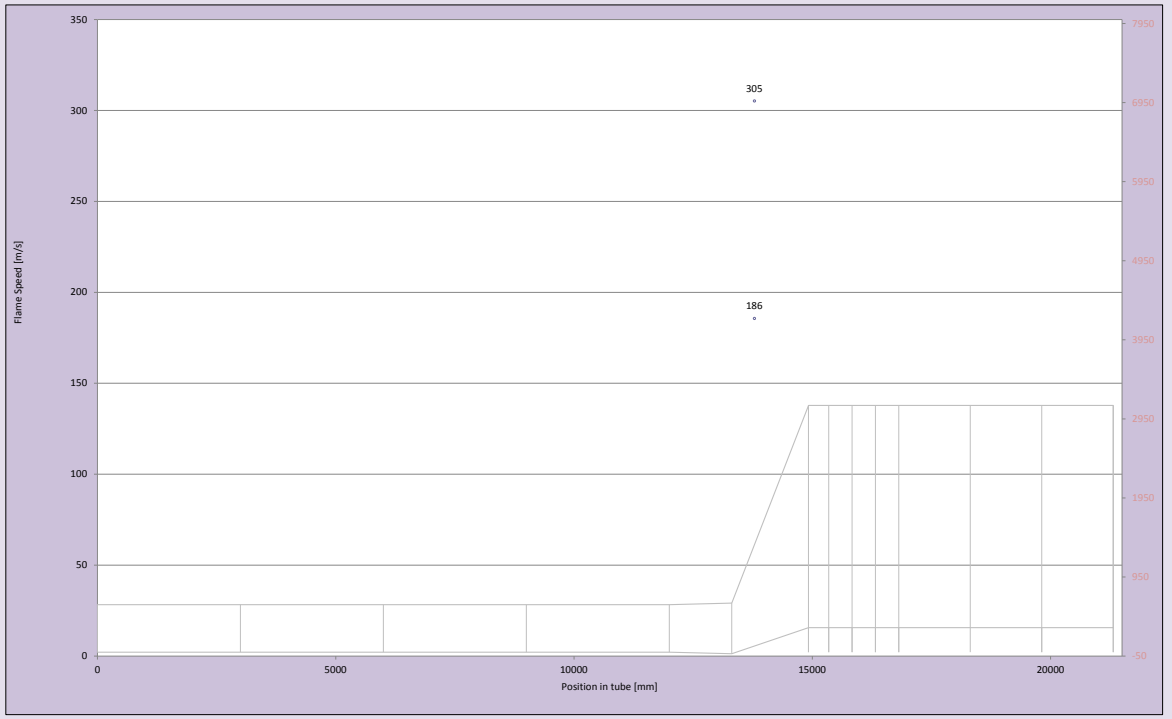
IP Number	Location label	Data Name	Position in tube (mm)	Flame arrival time (s)	Avg Flame speed from last sensor (m/s)
IP0	CD4-L6	sation probe 0	11758	15.90710	148
IP1	HR2-L5L	sation probe 1	14745	15.92829	146
IP2	HR2-L5M	sation probe 2	14745	15.93837	130
IP3	HR2-L5U	sation probe 3	14745	15.93968	128
IP4	HR3-R1L	sation probe 4	15140	15.92930	
IP5	HR3-R1LM	sation probe 5	15140	15.93163	
IP6	HR3-R1M	sation probe 6	15140	15.93443	
IP7	HR3-R1U	sation probe 7	15140	15.93260	
IP8	HR3-L1U	sation probe 8	15140	15.93327	
IP9	HE2-R1M	sation probe 9	16090	15.93437	
IP10	HR4-L1L	tion probe 10	16985	15.93638	
IP11	HR4-L1M	tion probe 11	16985	15.93594	
IP12	HR4-L1U	tion probe 12	16985	15.93130	
IP13	HR4-R1U	tion probe 13	16985	15.93060	
IP14	HR4-R3U	tion probe 14	17575	15.98286	
IP15	HR4-L5L	tion probe 15	18165	15.96226	
IP16	HR4-L5M	tion probe 16	18165	15.96105	
IP17	HR4-L5U	tion probe 17	18165	15.93622	
IP18	HR4-R5M	tion probe 18	18165	15.93667	
IP19	HR5-L2L	tion probe 19	18775	15.98501	
IP20	HR5-L2M	tion probe 20	18775	15.95408	
IP21	HR5-L2U	tion probe 21	18775	NW	
IP22	HR5-R2U	tion probe 22	18775	ND	
IP23	HR6-L1M	tion probe 23	19985	ND	

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



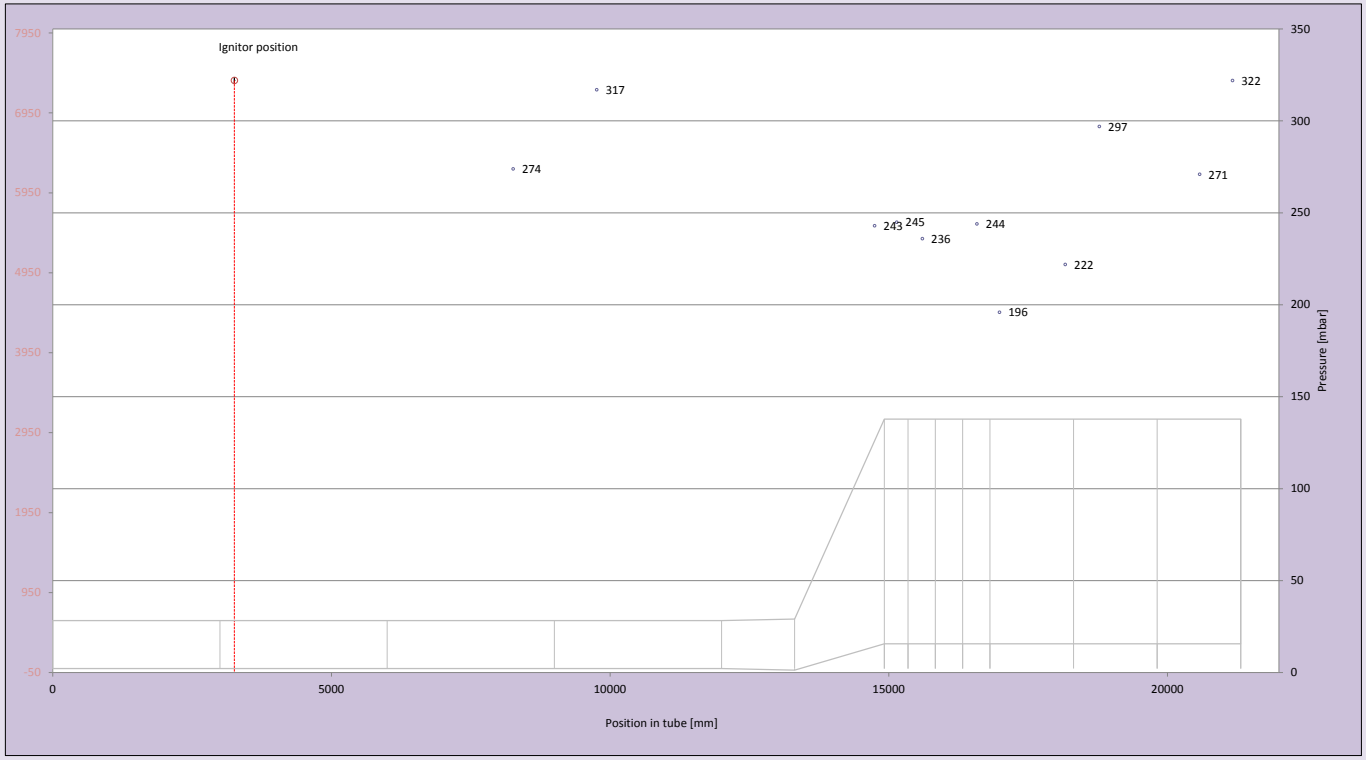
Location of igniter 3258 mm **Time of ignition** 15.84985983 seconds

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	15.9065	186
RA1	IP25	HR2-R2M	IP25	13785	15.8843	305
RA1	IP26	HR2-R2M	IP26	13785	NW	
RA2	IP27	HR2-R4M	IP27	14475	15.9276	
RA2	IP28	HR2-R4M	IP28	14475	15.9281	
RA2	IP29	HR2-R4M	IP29	14475	15.9303	
RA3	IP30	HR4-R3M	IP30	17575	15.9362	
RA3	IP31	HR4-R3M	IP31	17575	15.9364	
RA3	IP32	HR4-R3M	IP32	17575	15.9455	
RA4	IP33	HR4-R3L	IP33	17575	15.9445	
RA4	IP34	HR4-R3L	IP34	17575	15.9432	
RA4	IP35	HR4-R3L	IP35	17575	15.9427	



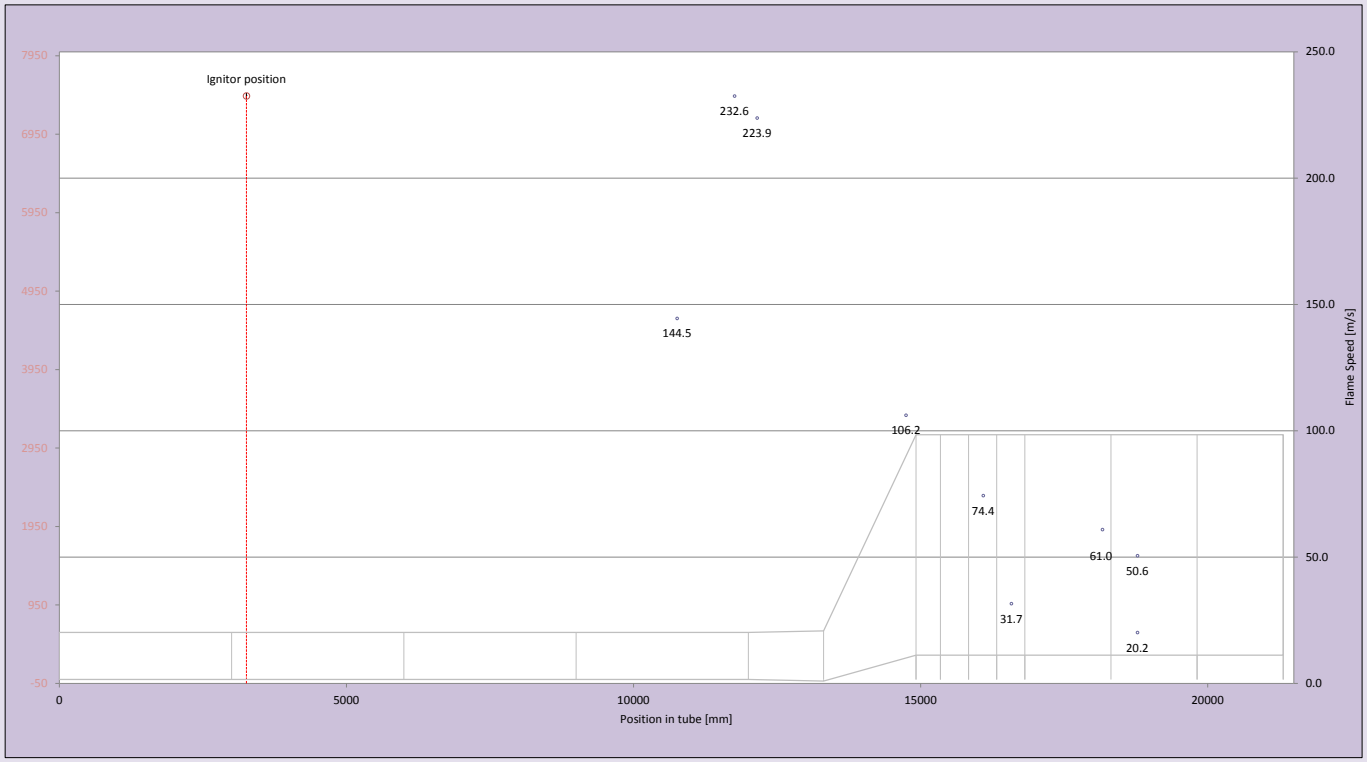
Location of igniter 3258 mm

Transducer number	Location	Position in tube [mm]	D_{Pmax} [mbar]	Time D_{Pmax} [sec]
KU0	CD3-R5	8258	274	15.9673
KU1	CD4-R2	9758	317	15.9677
KU2	HR2-T5	14745	243	15.9583
KU3	HR3-L1L	15140	245	15.9614
KU4	HE1-R1U	15600	236	15.9362
KU5	HE3-R1L	16580	244	15.9597
KU6	HR4-R1L	16985	196	15.9544
KU7	HR4-R5U	18165	222	15.9536
KU8	HR5-R2L	18775	297	15.9510
KU9	HR6-R3L	20575	271	15.9469
KU10	HR6-L5L	21165	322	15.9458



Location of igniter 3258 mm **Time of ignitio** 15.84985983 seconds

OP Number	Location label	Position in tube (mm)	Flame arrival time (s)	Average flame speed (m/s)
OP0	CD4-L4	10758	15.9018	144.5
OP1	CD4-R6	11758	15.9061	232.6
OP2	HR1-R1	12152	15.9078	223.9
OP3	HR2-R5M	14745	15.9322	106.2
OP4	HE1-T1	15600		
OP5	HE2-T1	16090	15.9503	74.4
OP6	HE3-T1	16580	15.9658	31.7
OP7	HR4-T1	16985	15.9386	-14.9
OP8	HR4-R1M	16985	15.9401	-15.8
OP9	HR4-R5L	18165	15.9594	61.0
OP10	HR5-T2	18775	15.9715	50.6
OP11	HR5-R2M	18775	15.9897	20.2



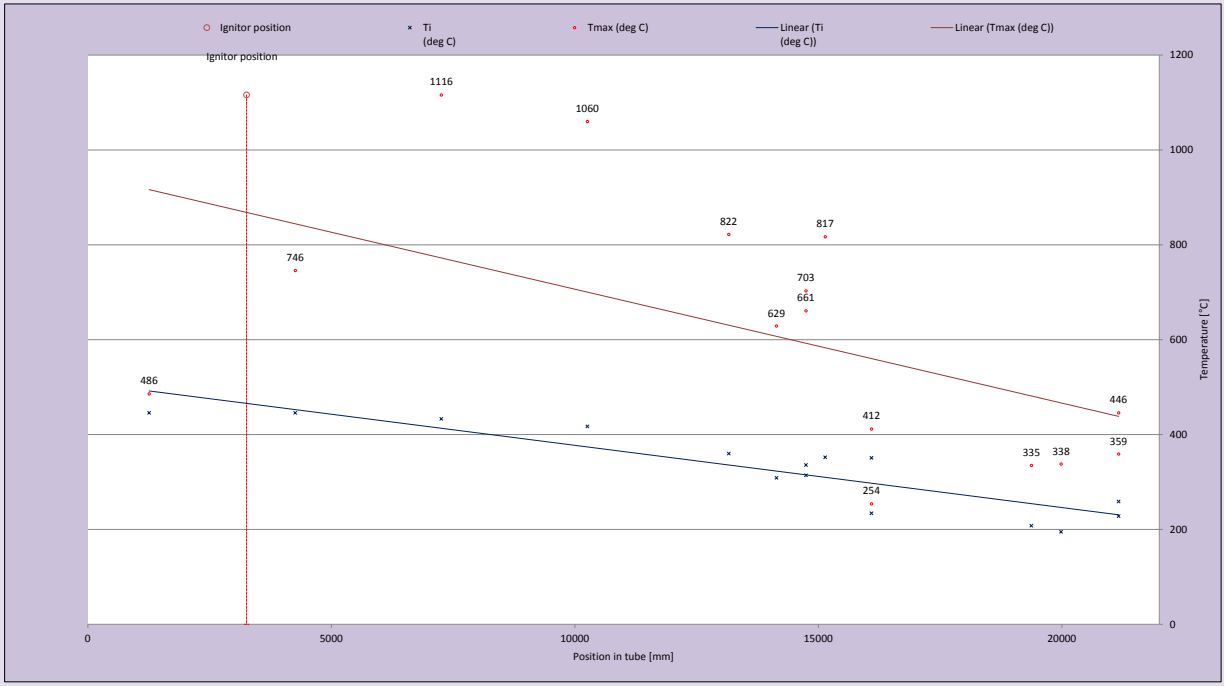
Location of igniter 3258 mm **Time of ignition** 15.84986 seconds

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	-		486	446
TC2	CD2-R3	4258	15.909	17	746	446
TC4	CD3-R3	7258	15.908	69	1116	433
TC6	CD4-R3	10258	15.913	111	1060	417
TC8	HR1-R2	13160	15.949	100	822	360
TC16	HR2-R3M	14140	15.944	116	629	309
TC17	HR2-R5L	14745	15.955	109	703	336
TC18	HR2-R5U	14745	15.974	93	661	314
TC19	HR3-L1M	15140	15.970	99	817	352
TC20	HE2-R1L	16090	15.984	96	412	351
TC21	HE2-R1U	16090	15.992	90	254	234
TC22	HR5-R4M	19375	16.069	74	335	208
TC23	HR6-R1M	19985	16.120	62	338	195
TC24	HR6-R5L	21165	16.334	37	359	228
TC25	HR6-R5U	21165	16.315	38	446	259

surface thermocouples [not plotted]

TC1	CD1-T2	1508			146	143
TC3	CD2-T2	4508			115	113
TC5	CD3-T2	7508			36	35
TC7	CD4-T2	10508			68	66

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



Pressure


Name
Unit
Y
X
Maximum
Time_Max
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15.98261
0.289584726...
Kulite pressure 1
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15.98261
0.353942898...
Kulite pressure 2
0.643744281...
15.98261
0.761758319...
Kulite pressure 3
0.143295231...
15.98261
0.263552557...
Kulite pressure 4
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15.98261
0.249982390...
Kulite pressure 5
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0.285896670...
Kulite pressure 6
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0.207666682...
Kulite pressure 7
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Kulite pressure 8
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P2:
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Y-Cursor1:
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Z-Cursor1:
0
Y2-Cursor1
0
X-Cursor2:
Y-Cursor2:
Z-Cursor2:
Y2-Cursor2
dX-Cursor:
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dY-Cursor:
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dY-Cursor/
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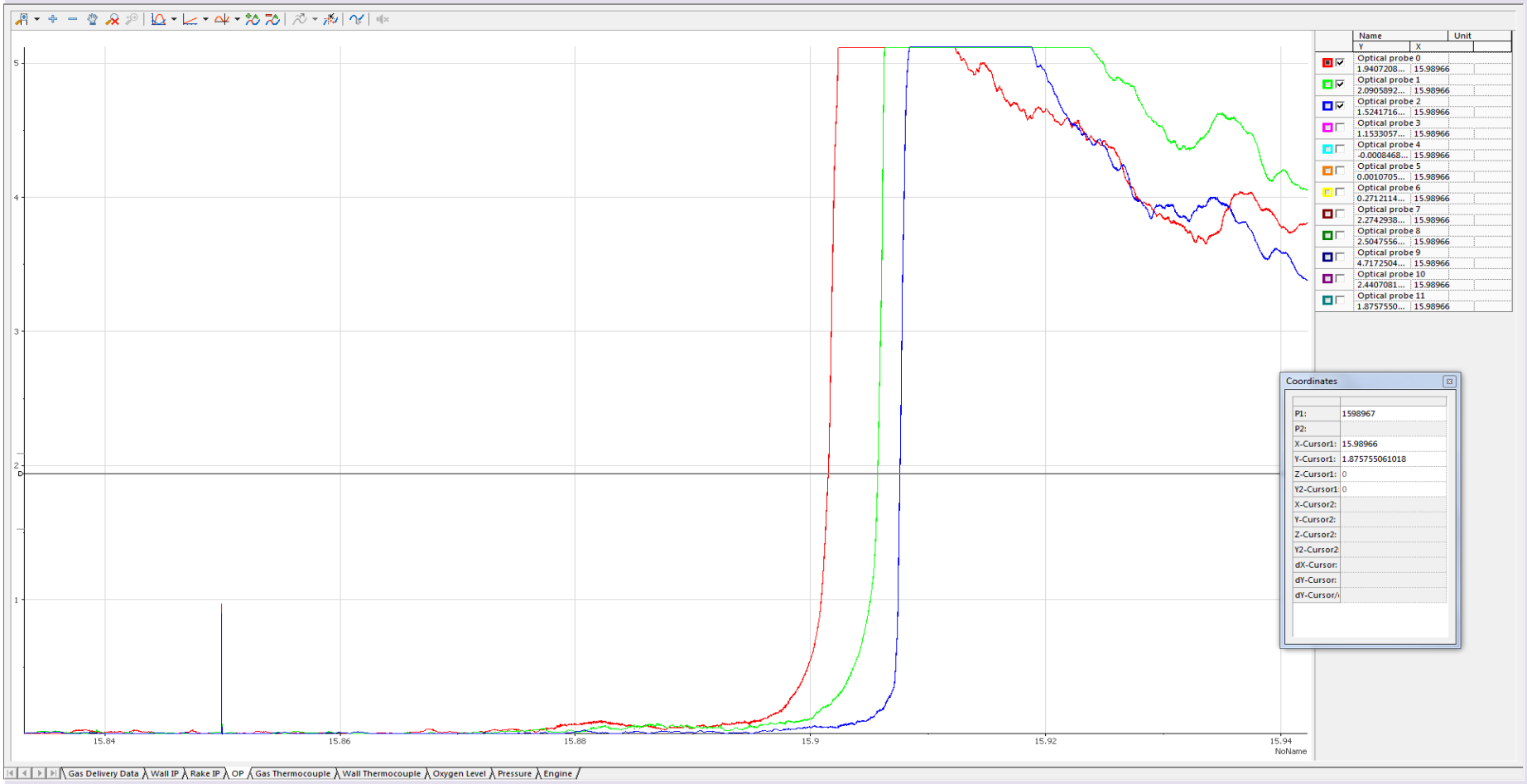
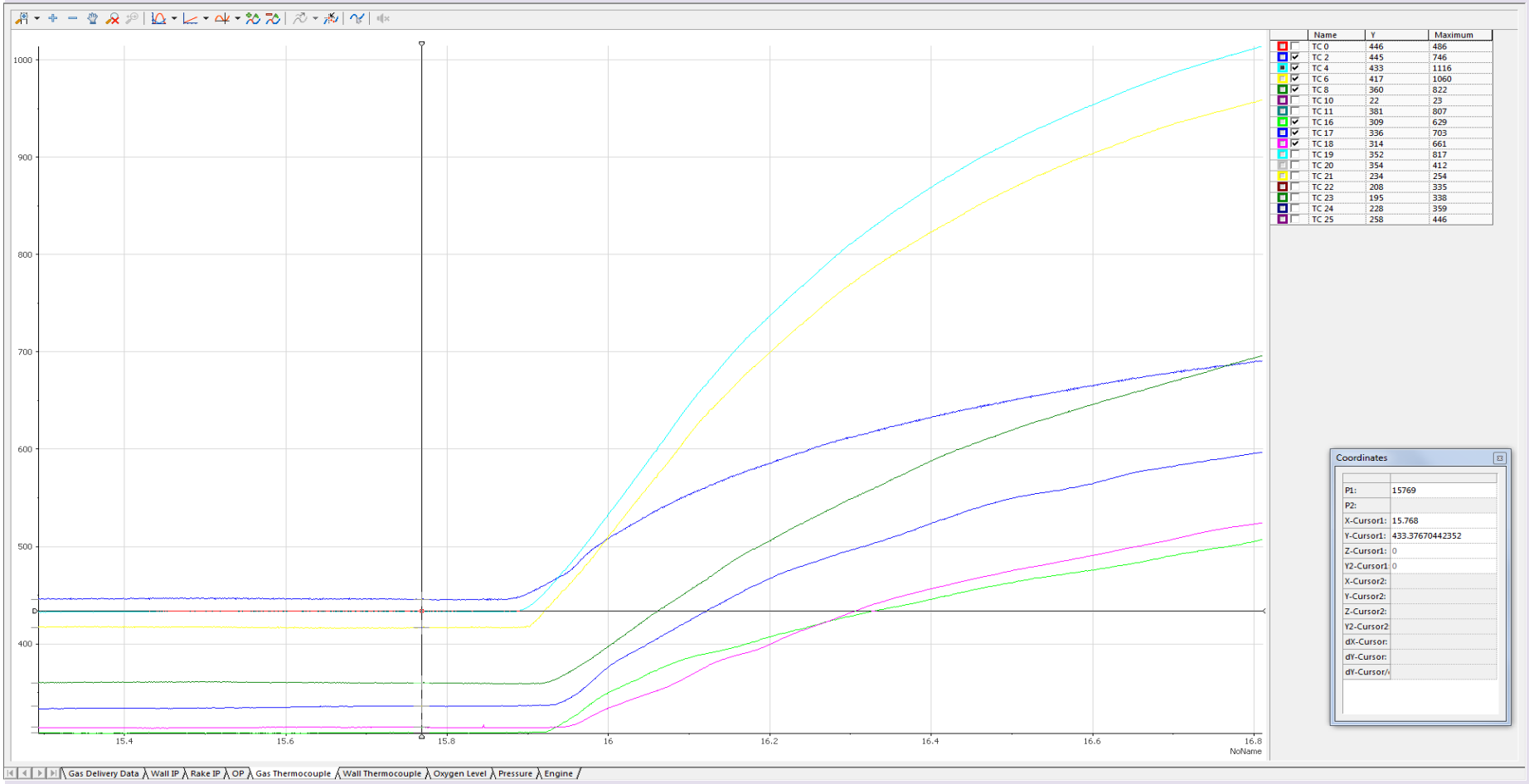
15.8
15.85
15.9
15.95
16
16.05
NoName
Gas Delivery Data
Wall IP
Rake IP
OP
Gas Thermocouple
Wall Thermocouple
Oxygen Level
Pressure
Engine

Optical Probes



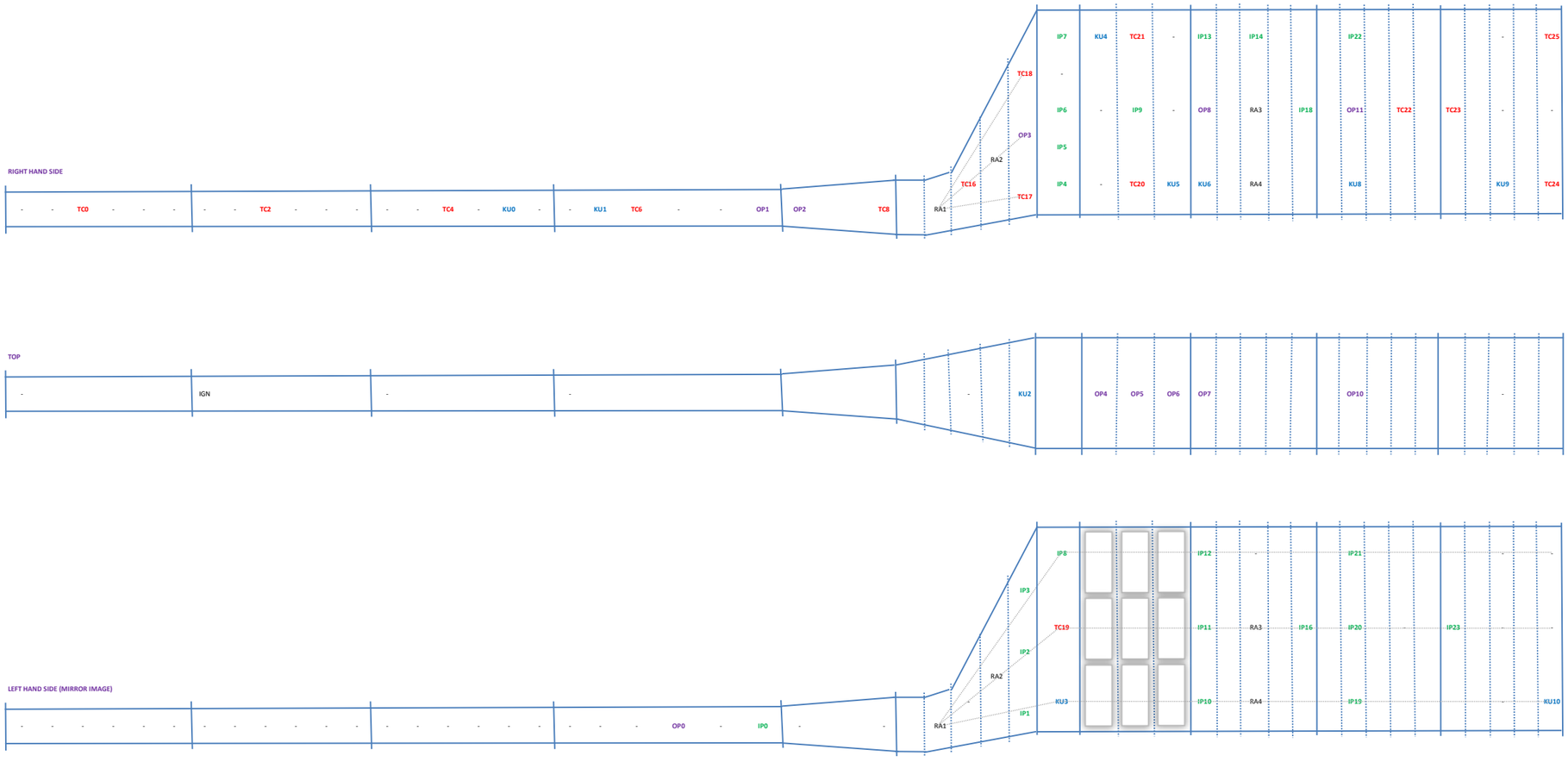
Ionisation Probes

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	11/4" 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


RIGHT HAND SIDE
TC0
TC2
TC4
KU0
KU1
TC6
OP1
OP2
TC8
RA1
TC16
TC18
RA2
OP3
TC17
IP7
KU4
TC21
IP13
IP14
IP22
TC25
IP6
IP9
OP8
RA3
IP18
OP11
TC22
TC23
IP5
IP4
TC20
KU5
KU6
RA4
KU8
KU9
TC24
TOP
IGN
KU2
OP4
OP5
OP6
OP7
OP10
LEFT HAND SIDE (MIRROR IMAGE)
OP0
IP0
IP8
IP3
TC19
IP2
KU3
IP1
IP12
IP11
IP10
IP21
IP16
IP20
IP23
KU10