

Date	27 February 2016
Time	15:33:52
Test Number	3
Mixture Composition	60% H2 40% CH4
Ambient Temperature	6°C
Ambient Pressure	970
Wind Speed	5 m/s
Wind direction	NW
Relative Humidity	80.00%
Mass Flow	10.001 kg/s
Equivalence Ratio	0.55

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

Weather: Cold and sunny with a light North Westerly breeze.  
 Rig configuration: 4 x 3m circular duct; expansion section and HRSG attached.  
 Open ended - end plate not attached  
 igniter 258mm from beginning of 2nd circular duct section  
 Engine Speed: 40%; 11,800 rpm

1st of HRSG tests with 60% H2 and 40% CH4 at an EQR of 0.55.  
 The test gave a moderate combustion event and all sensor provided a good response.

Flame speed, on both IP and OP's, showed flame speeds between 300 and 400 m/s.

**Ionisation Probes**

**Ionisation Rakes**

**Optical Probes**

Max overpressure  
 mbar

Max. temperature  
 °C

Max. flame speed  
 m/s

Max. flame speed  
 m/s

Max. flame speed  
 m/s

Initial Temperature  
 °C

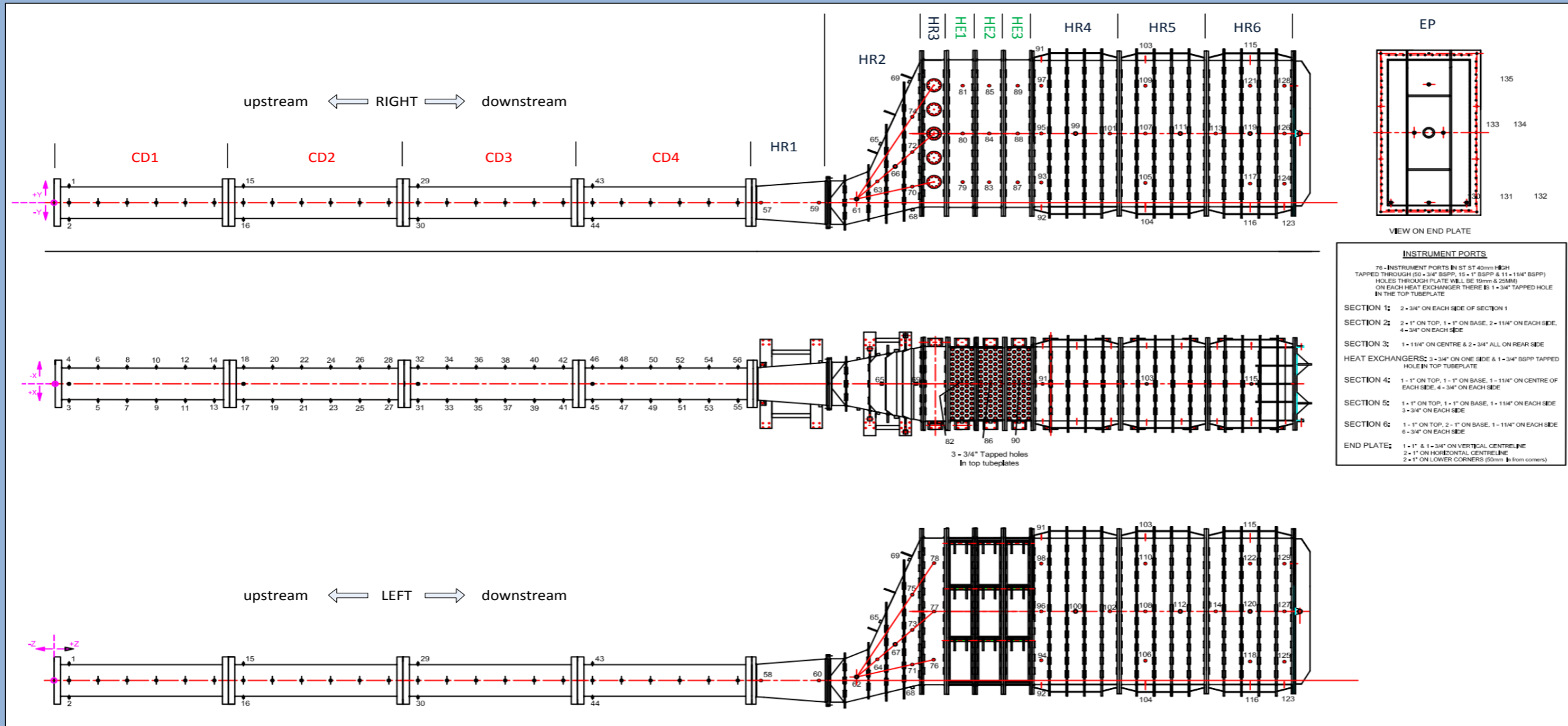
Location of Max. Overpressure  
 sensor   
 label   
 distance  mm

Location of Max. Temperature  
 sensor   
 label   
 distance  mm

Location of Max. Flame Speed  
 sensor   
 label   
 distance  mm

Location of Max. Flame Speed  
 sensor   
 label   
 distance  mm

Location of Max. Flame Speed  
 sensor   
 label   
 distance  mm



**INSTRUMENT PORTS**

78 - INSTRUMENT PORTS IN ST 31 40mm HIGH TAPPED THROUGH 5/16" BSPP, 15 - 1" BSPP & 11 - 1/4" 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 - 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, 8 - 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 (Shown from corners)

**Naming Convention**

Section Identifier i.e. HE, HR, CD or EP	<b>HR 1 - R 1 U</b>	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**

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

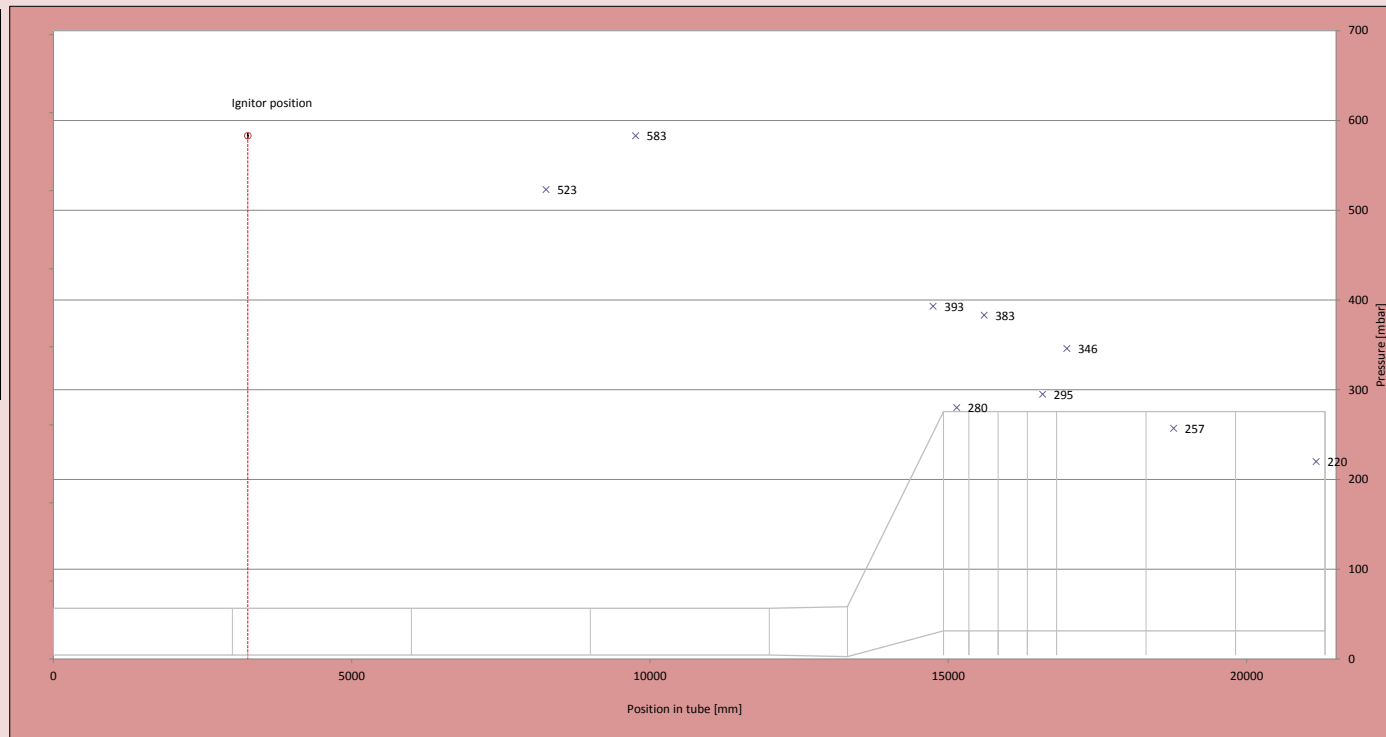
There are 13 sections on the rig

- 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

0	3000	6000	9000	12000	13310	14920	15345	15835	16325	16815	18315	19815	21315	21315	19815	16815	16325	15835	15345	14920	13310	12000	9000	6000	3000	0	
600	600	600	600	600	620	3120	3120	3120	3120	3120	3120	3120	3120	310	310	310	310	310	310	310	310	-20	0	0	0	0	0

Location of igniter  mm

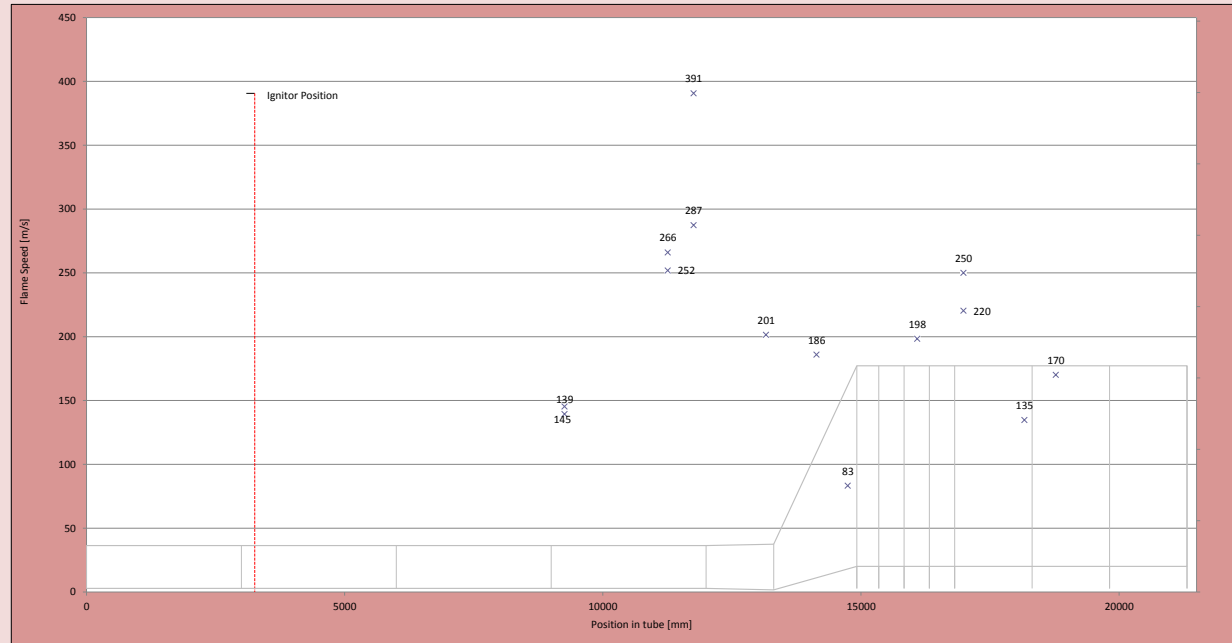
Transducer number	Location	Position in tube [mm]	$\Delta P_{max}$ [mbar]	Time $\Delta P_{max}$ [mbar]
KU6	CD3-R5	8258	523	17.0974
KU7	CD4-R2	9758	583	17.0974
KU8	HR2-T5	14745	393	17.0928
KU9	HR3-L1L	15140	280	17.0937
KU0	HE1-R1U	15600	383	17.0935
KU1	HE3-R1L	16580	295	17.0932
KU2	HR4-R1U	16985	346	17.0980
KU4	HR5-L2M	18775	257	17.0976
KU5	HR6-LSM	21165	220	17.1010
KU3	HR5-R2L	18775	298	17.0976
KU10	#N/A	#N/A		
KU11	#N/A	#N/A		
PCB	#N/A	#N/A		



Location of igniter 3258 mm Time of ignition 17.0192 seconds

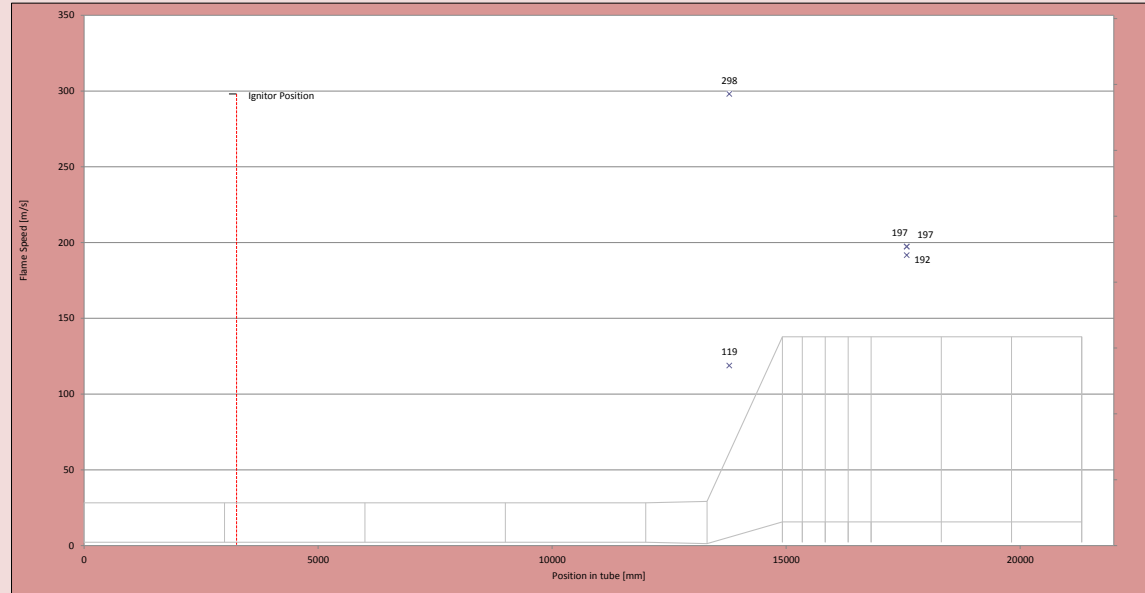
IP Number	Location label	Position in tube (mm)	Flame arrival time (s)	Avg Flame speed from last sensor (m/s)
IP4	CD4-L1	9258	17.0622	139
IP5	CD4-R1	9258	17.0605	145
IP2	CD4-L5	11258	17.0698	266
IP3	CD4-R5	11258	17.0684	252
IP0	CD4-L6	11758	17.0715	287
IP1	CD4-R6	11758	17.0697	391
IP6	HR1-R2	13160	17.0767	201
IP7	HR2-R3M	14140	17.0819	186
IP8	HR2-R5M	14745	17.0892	83
IP10	HE2-R1M	16090	17.0918	198
IP12	HR4-R1M	16985	17.0954	250
IP13	HR4-L1L	16985	17.0952	220
IP14	HR4-R5M	18165	17.1041	135
IP15	HR5-R2M	18775		
IP16	HR5-L2L	18775	17.1057	170
IP17	HR6-R1M	19985		
IP19	HR6-L3L	20575		
IP18	HR6-R5M	21165		
IP20	HR6-L5L	21165		
IP9	#N/A	#N/A		
IP11	#N/A	#N/A		
IP21	#N/A	#N/A		
IP22	#N/A	#N/A		
IP23	#N/A	#N/A		

Flame signature at end of HRSG (i.e. sensors IP17 to IP20) was relatively weak and hence difficult to ascertain time of arrival of flame at these sensors



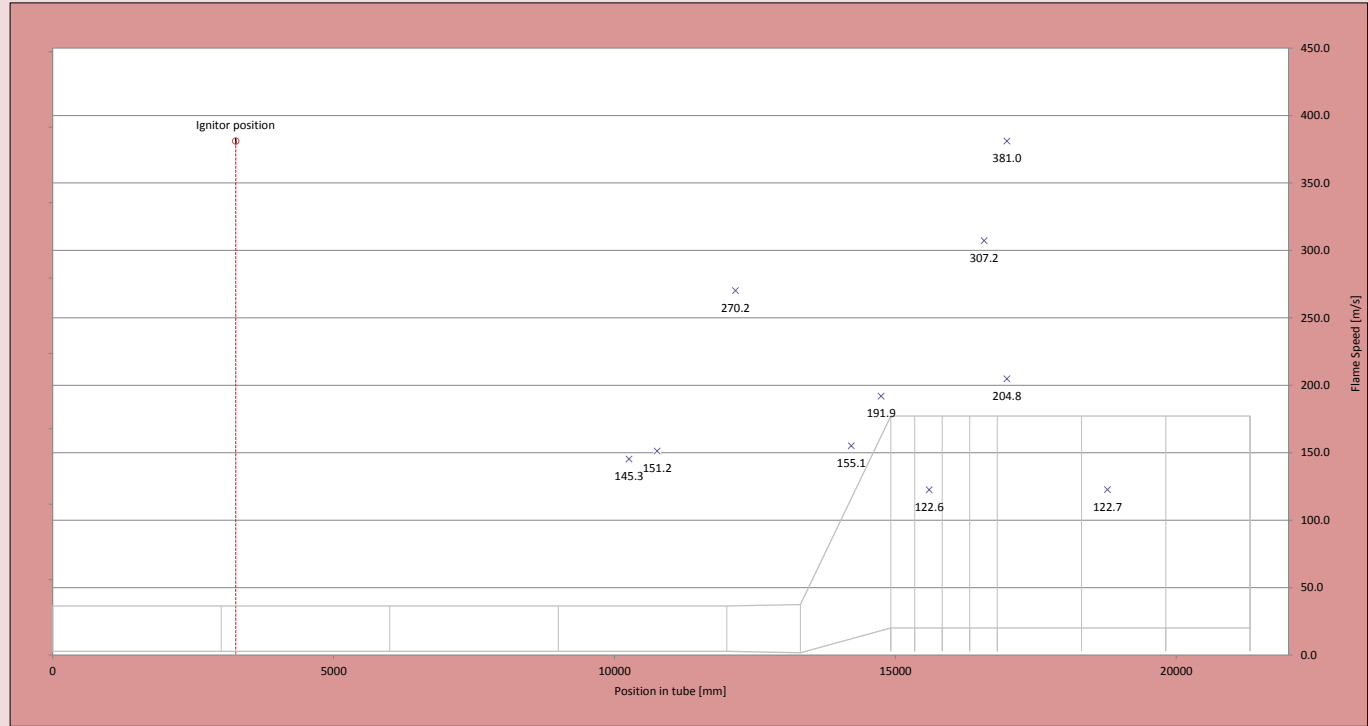
Location of igniter  mm Time of ignition  seconds

Rake Number	IP Number	Location label	Position in tube (mm)	Flame arrival time (s)	Avg Flame speed from last sensor (m/s)
RA1	IP24	HR2-R2M	13785	17.0783	298
RA1	IP25	HR2-R2M	13785		
RA1	IP26	HR2-R2M	13785	17.0777	119
RA2	IP27	HR2-R4M	14475		
RA2	IP28	HR2-R4M	14475		
RA2	IP29	HR2-R4M	14475		
RA3	IP30	HR4-R3M	17575	17.0975	197
RA3	IP31	HR4-R3M	17575	17.0975	197
RA3	IP32	HR4-R3M	17575	17.0975	192
RA4	IP33	HR5-R4M	19375		
RA4	IP34	HR5-R4M	19375		
RA4	IP35	HR5-R4M	19375		



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)
OP11	CD4-L3	10258	17.0674	145.3
OP10	CD4-R4	10758	17.0688	151.2
OP0	HR1-R1	12152	17.0740	270.2
OP1	HR2-T3	14215	17.0898	155.1
OP2	HR2-LSM	14745	17.0908	191.9
OP3	HE1-T1	15600	17.1011	122.6
OP4	HE3-T1	16580	17.1043	307.2
OP5	HR4-R1L	16985	17.0976	204.8
OP6	HR4-T1	16985	17.0971	381.0
OP7	HR5-T2	18775	17.1117	122.7
OP8	HR6-T3	20575		
OP9	HR6-RSU	21165		
OP12	#N/A	#N/A		
OP13	#N/A	#N/A		
OP14	#N/A	#N/A		
OP15	#N/A	#N/A		

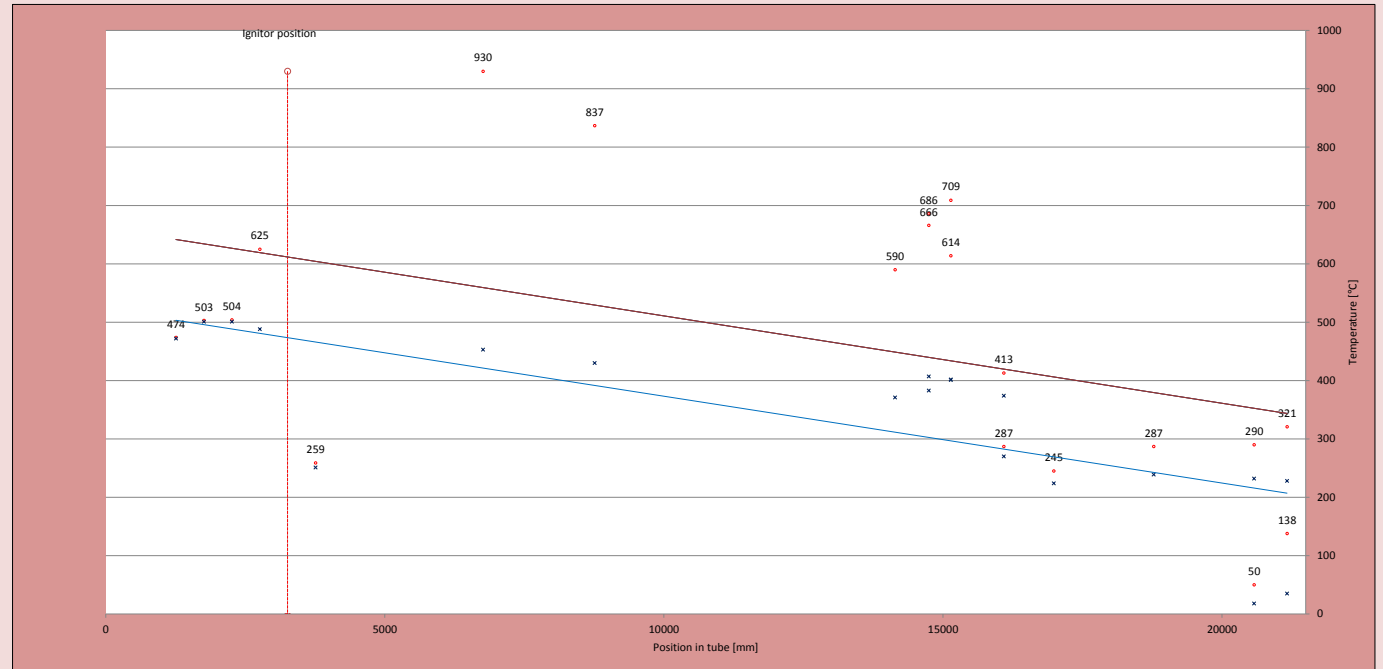


Location of igniter 3258 mm

Thermocouple number	Location	Position in tube (mm)	T <sub>max</sub> (deg C)	T <sub>i</sub> (deg C)
TC0	CD1-R3	1258	474	472
TC2	CD1-R4	1758	503	501
TC3	CD1-R5	2258	504	501
TC4	CD1-R6	2758	625	488
TC5	CD2-R2	3758	259	251
TC7	CD3-R2	6758	930	453
TC9	CD3-R6	8758	837	430
TC11	#N/A	#N/A		
TC12	#N/A	#N/A		
TC13	#N/A	#N/A		
TC14	#N/A	#N/A		
TC15	#N/A	#N/A		
TC16	HR2-R5L	14745	686	407
TC17	HE2-R1U	16090	287	270
TC18	HR6-R3L	20575	50	18
TC19	#N/A	#N/A		
TC20	HE2-R1L	16090	413	374
TC22	#N/A	#N/A		
TC23	HR6-R5L	21165	138	35
TC24	HR2-L3M	14140	590	371
TC25	HR2-L5L	14745	666	383
TC26	HR3-L1M	15140	709	401
TC27	HR3-L1U	15140	614	402
TC28	HR4-L1M	16985	245	224
TC29	HR5-L2U	18775	287	239
TC30	HR6-L3U	20575	290	232
TC31	HR6-L5U	21165	321	228

surface thermocouples [not plotted]

TC1	CD1-T2	1508		
TC6	CD2-T2	4508		
TC8	CD3-T2	7508	257	250
TC10	CD4-T2	10508	227	223
TC21	HR5-R1M	18455	39	37



Sensor	OLD DESIGNATION	NEW DESIGNATION	Section	Section Number	Side	Horizontal Location	Vertical Location	PORT REF	SIZE	"X"	"Y"	"Z"
-		CD1-T1	CD	1	T	1		1	1" BSPP	0	298	258
TC1	TS1-1	CD1-T2	CD	1	T	2		NA	SURFACE	0	298	1508
-		CD1-B1	CD	1	B	1		2	1" BSPP	0	-298	258
-	NS1-1	CD1-R1	CD	1	R	1		3	3/4" BSPP	298	0	258
-	FS1-1	CD1-L1	CD	1	L	1		4	3/4" BSPP	-298	0	258
-	NS1-2	CD1-R2	CD	1	R	2		5	3/4" BSPP	298	0	758
-	FS1-2	CD1-L2	CD	1	L	2		6	3/4" BSPP	-298	0	758
TC0	NS1-3	CD1-R3	CD	1	R	3		7	3/4" BSPP	298	0	1258
-	FS1-3	CD1-L3	CD	1	L	3		8	3/4" BSPP	-298	0	1258
TC2	NS1-4	CD1-R4	CD	1	R	4		9	3/4" BSPP	298	0	1758
-	FS1-4	CD1-L4	CD	1	L	4		10	3/4" BSPP	-298	0	1758
TC3	NS1-5	CD1-R5	CD	1	R	5		11	3/4" BSPP	298	0	2258
-	FS1-5	CD1-L5	CD	1	L	5		12	3/4" BSPP	-298	0	2258
TC4	NS1-6	CD1-R6	CD	1	R	6		13	3/4" BSPP	298	0	2758
-	FS1-6	CD1-L6	CD	1	L	6		14	3/4" BSPP	-298	0	2758
IGN		CD2-T1	CD	2	T	1		15	1" BSPP	0	298	3258
TC6	TS2-1	CD2-T2	CD	2	T	2		NA	SURFACE	0	298	4508
-		CD2-B1	CD	2	B	1		16	1" BSPP	0	-298	2358
-	NS2-1	CD2-R1	CD	2	R	1		17	3/4" BSPP	298	0	3258
-	FS2-1	CD2-L1	CD	2	L	1		18	3/4" BSPP	-298	0	3258
TC5	NS2-2	CD2-R2	CD	2	R	2		19	3/4" BSPP	298	0	3758
-	FS2-2	CD2-L2	CD	2	L	2		20	3/4" BSPP	-298	0	3758
-	NS2-3	CD2-R3	CD	2	R	3		21	3/4" BSPP	298	0	4258
-	FS2-3	CD2-L3	CD	2	L	3		22	3/4" BSPP	-298	0	4258
-	NS2-4	CD2-R4	CD	2	R	4		23	3/4" BSPP	298	0	4758
-	FS2-4	CD2-L4	CD	2	L	4		24	3/4" BSPP	-298	0	4758
-	NS2-5	CD2-R5	CD	2	R	5		25	3/4" BSPP	298	0	5258
-	FS2-5	CD2-L5	CD	2	L	5		26	3/4" BSPP	-298	0	5258
-	NS2-6	CD2-R6	CD	2	R	6		27	3/4" BSPP	298	0	5758
-	FS2-6	CD2-L6	CD	3	L	6		28	3/4" BSPP	-298	0	5758
-		CD3-T1	CD	3	T	1		29	1" BSPP	0	298	6258
TC8	TS1-1	CD3-T2	CD	3	T	2		NA	SURFACE	0	298	7508
-		CD3-B1	CD	3	B	1		30	1" BSPP	0	-298	6258
-	NS3-1	CD3-R1	CD	3	R	1		31	3/4" BSPP	298	0	6258
-	FS3-1	CD3-L1	CD	3	L	1		32	3/4" BSPP	-298	0	6258
TC7	NS3-2	CD3-R2	CD	3	R	2		33	3/4" BSPP	298	0	6758
-	FS3-2	CD3-L2	CD	3	L	2		34	3/4" BSPP	-298	0	6758
-	NS3-3	CD3-R3	CD	3	R	3		35	3/4" BSPP	298	0	7258
-	FS3-3	CD3-L3	CD	3	L	3		36	3/4" BSPP	-298	0	7258
-	NS3-4	CD3-R4	CD	3	R	4		37	3/4" BSPP	298	0	7758
-	FS3-4	CD3-L4	CD	3	L	4		38	3/4" BSPP	-298	0	7758
KU6	NS3-5	CD3-R5	CD	3	R	5		39	3/4" BSPP	298	0	8258
-	FS3-5	CD3-L5	CD	3	L	5		40	3/4" BSPP	-298	0	8258
TC9	NS3-6	CD3-R6	CD	3	R	6		41	3/4" BSPP	298	0	8758
-	FS3-6	CD3-L6	CD	3	L	6		42	3/4" BSPP	-298	0	8758
-		CD4-T1	CD	4	T	1		43	1" BSPP	0	298	9258
TC10	TS1-1	CD4-T2	CD	4	T	2		NA	SURFACE	0	298	10508
-		CD4-B1	CD	4	B	1		44	1" BSPP	0	-298	9258
IP5	NS4-1	CD4-R1	CD	4	R	1		45	3/4" BSPP	298	0	9258
IP4	FS4-1	CD4-L1	CD	4	L	1		46	3/4" BSPP	-298	0	9258
KU7	NS4-2	CD4-R2	CD	4	R	2		47	3/4" BSPP	298	0	9758
-	FS4-2	CD4-L2	CD	4	L	2		48	3/4" BSPP	-298	0	9758
-	NS4-3	CD4-R3	CD	4	R	3		49	3/4" BSPP	298	0	10258
OP11	FS4-3	CD4-L3	CD	4	L	3		50	3/4" BSPP	-298	0	10258
OP10	NS4-4	CD4-R4	CD	4	R	4		51	3/4" BSPP	298	0	10758
-	FS4-4	CD4-L4	CD	4	L	4		52	3/4" BSPP	-298	0	10758
IP3	NS4-5	CD4-R5	CD	4	R	5		53	3/4" BSPP	298	0	11258
IP2	FS4-5	CD4-L5	CD	4	L	5		54	3/4" BSPP	-298	0	11258
IP1	NS4-6	CD4-R6	CD	4	R	6		55	3/4" BSPP	298	0	11758



Sensor	OLD DESIGNATION	NEW DESIGNATION	Section	Section Number	Side	Horizontal Location	Vertical Location	PORT REF	SIZE	"X"	"Y"	"Z"
IP0	FS4-6	CD4-L6	CD	4	L	6		56	3/4" BSPP	-298	0	11758
OP0		HR1-R1	HR	1	R	1		57	3/4" BSPP	308	0	12152
-		HR1-L1	HR	1	L	1		58	3/4" BSPP	-308	0	12152
IP6		HR1-R2	HR	1	R	2		59	3/4" BSPP	393	0	13160
-		HR1-L2	HR	1	L	2		60	3/4" BSPP	-393	0	13160
RA1		HR2-R2M	HR	2	R	2	M	61	11/4" BSPP	448	70	13785
RA1		HR2-L2M	HR	2	L	2	M	62	11/4" BSPP	-448	70	13785
IP7		HR2-R3M	HR	2	R	3	M	63	3/4" BSPP	528	410	14140
TC24		HR2-L3M	HR	2	L	3	M	64	3/4" BSPP	-528	410	14140
OP1		HR2-T3	HR	2	T	3		65	1" BSPP	0	1122	14215
RA2		HR2-R4M	HR	2	R	4	M	66	11/4" BSPP	598	700	14475
RA2		HR2-L4M	HR	2	L	4	M	67	11/4" BSPP	-598	700	14475
-		HR2-B5	HR	2	B	5		68	1" BSPP	0	-100	14745
KU8		HR2-T5	HR	2	T	5		69	1" BSPP	0	2315	14745
TC16		HR2-R5L	HR	2	R	5	L	70	3/4" BSPP	662	310	14745
TC25		HR2-L5L	HR	2	L	5	L	71	3/4" BSPP	-662	310	14745
IP8		HR2-R5M	HR	2	R	5	M	72	3/4" BSPP	662	975	14745
OP2		HR2-L5M	HR	2	L	5	M	73	3/4" BSPP	-662	975	14745
-		HR2-R5U	HR	2	R	5	U	74	3/4" BSPP	662	1660	14745
-		HR2-L5U	HR	2	L	5	U	75	3/4" BSPP	-662	1660	14745
KU9		HR3-L1L	HR	3	L	1	L	76	3/4" BSPP	-700	400	15140
TC26		HR3-L1M	HR	3	L	1	M	77	11/4" BSPP	-700	1335	15140
TC27		HR3-L1U	HR	3	L	1	U	78	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
KU0		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
IP10		HE2-R1M	HE	2	R	1	M	84	3/4" BSPP	700	1335	16090
TC17		HE2-R1U	HE	2	R	1	U	85	3/4" BSPP	700	2270	16090
KU1		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
OP3		HE1-T1	HE	1	T	1		82	3/4" BSPP HOLE	-47	2735	15600
-		HE2-T1	HE	2	T	1		86	3/4" BSPP HOLE	0	2735	16090
OP4		HE3-T1	HE	3	T	1		90	3/4" BSPP HOLE	-47	2735	16580
OP6		HR4-T1	HR	4	T	1		91	1" BSPP	0	2735	16985
-		HR4-B1	HR	4	B	1		92	1" BSPP	0	-65	16985
OP5		HR4-R1L	HR	4	R	1	L	93	3/4" BSPP	700	400	16985
IP13		HR4-L1L	HR	4	L	1	L	94	3/4" BSPP	-700	400	16985
IP12		HR4-R1M	HR	4	R	1	M	95	3/4" BSPP	700	1335	16985
TC28		HR4-L1M	HR	4	L	1	M	96	3/4" BSPP	-700	1335	16985
KU2		HR4-R1U	HR	4	R	1	U	97	3/4" BSPP	700	2270	16985
-		HR4-L1U	HR	4	L	1	U	98	3/4" BSPP	-700	2270	16985
RA3		HR4-R3M	HR	4	R	3	M	99	11/4" BSPP	700	1335	17575
RA3		HR4-L3M	HR	4	L	3	M	100	11/4" BSPP	-700	1335	17575
IP14		HR4-R5M	HR	4	R	5	M	101	3/4" BSPP	700	1335	18165
-		HR4-L5M	HR	4	L	5	M	102	3/4" BSPP	-700	1335	18165
TC21		HR5-R1M	HR	5	R	1	M	NA	SURFACE	700	1200	18455
OP7		HR5-T2	HR	5	T	2		103	1" BSPP	0	2735	18775
-		HR5-B2	HR	5	B	2		104	1" BSPP	0	-65	18775
KU3		HR5-R2L	HR	5	R	2	L	105	3/4" BSPP	700	400	18775
IP16		HR5-L2L	HR	5	L	2	L	106	3/4" BSPP	-700	400	18775
IP15		HR5-R2M	HR	5	R	2	M	107	3/4" BSPP	700	1335	18775
KU4		HR5-L2M	HR	5	L	2	M	108	3/4" BSPP	-700	1335	18775
-		HR5-R2U	HR	5	R	2	U	109	3/4" BSPP	700	2270	18775
TC29		HR5-L2U	HR	5	L	2	U	110	3/4" BSPP	-700	2270	18775
RA4		HR5-R4M	HR	5	R	4	M	111	11/4" BSPP	700	1335	19375
RA4		HR5-L4M	HR	5	L	4	M	112	11/4" BSPP	-700	1335	19375
IP17		HR6-R1M	HR	6	R	1	M	113	3/4" BSPP	700	1335	19985

Sensor	OLD DESIGNATION	NEW DESIGNATION	Section	Section Number	Side	Horizontal Location	Vertical Location	PORT REF	SIZE	"X"	"Y"	"Z"
-		HR6-L1M	HR	6	L	1	M	114	3/4" BSPP	-700	1335	19985
OP8		HR6-T3	HR	6	T	3		115	1" BSPP	0	2735	20575
-		HR6-B3	HR	6	B	3		116	3/4" BSPP	0	-65	20575
TC18		HR6-R3L	HR	6	R	3	L	117	3/4" BSPP	700	400	20575
IP19		HR6-L3L	HR	6	L	3	L	118	3/4" BSPP	-700	400	20575
-		HR6-R3M	HR	6	R	3	M	119	11/4" BSPP	700	1335	20575
-		HR6-L3M	HR	6	L	3	M	120	11/4" BSPP	-700	1335	20575
-		HR6-R3U	HR	6	R	3	U	121	3/4" BSPP	700	2270	20575
TC30		HR6-L3U	HR	6	L	3	U	122	3/4" BSPP	-700	2270	20575
-		HR6-B5	HR	6	B	5		123	1" BSPP	0	-65	21165
TC23		HR6-R5L	HR	6	R	5	L	124	3/4" BSPP	700	400	21165
IP20		HR6-L5L	HR	6	L	5	L	125	3/4" BSPP	-700	400	21165
IP18		HR6-R5M	HR	6	R	5	M	126	3/4" BSPP	700	1335	21165
KU5		HR6-L5M	HR	6	L	5	M	127	3/4" BSPP	-700	1335	21165
OP9		HR6-R5U	HR	6	R	5	U	128	3/4" BSPP	700	2270	21165
TC31		HR6-L5U	HR	6	L	5	U	129	3/4" BSPP	-700	2270	21165
-		EP-1L	EP			1	L	130	1" BSPP	650	-15	21330
-		EP-2L	EP			2	L	131	1" BSPP	0	-15	21330
-		EP-3L	EP			3	L	132	1" BSPP	-650	-15	21330
-		EP-1M	EP			1	M	133	1" BSPP	250	1335	21330
-		EP-2M	EP			2	M	134	1" BSPP	-250	1335	21330
-		EP-1U	EP			1	U	135	3/4" BSPP	0	2270	21330