Outotec (USA) Inc. Energy Products

Flue Gas Plug Flow Residence Time Estimation

Outotec

Project/Proposal Number: DQ-150414
Project Name: Barry - Biomass UK No. 2 LTD
Description: Plug Flow Residence Time Estimation from After Last Air Injection to Boiler Inlet (Note 7) - Waste Wood Fuel Only
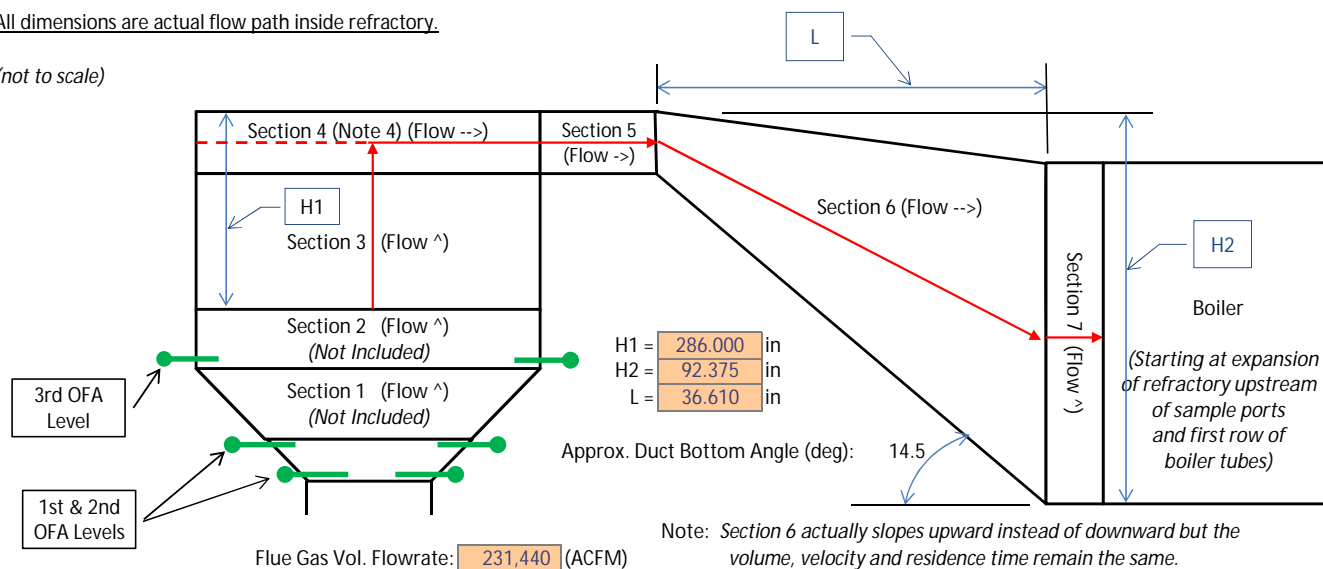Case: 105% MCR with 14.3 MJ/kg Waste Wood fuel and 935 °C Flue Gas (Worst Case Res. Time)
Date: 6/17/2016   By: T.Kast
Revision: Rev. 0

All dimensions are actual flow path inside refractory.

(not to scale)

H1 = 286.000 in
H2 = 92.375 in
L = 36.610 in

Approx. Duct Bottom Angle (deg): 14.5

Flue Gas Vol. Flowrate: 231,440 (ACFM)

Note: *Section 6 actually slopes upward instead of downward but the volume, velocity and residence time remain the same.*

Section (Note)	Avg. Flow Path Length, Z (in) (2)	Entry X-sect. L (in) (3)	Entry X-sect. W (in) (3)	Exit X-sect. L (in)	Exit X-sect. W (in)	Entry X-sect. Area (ft^2)	Exit X-sect. Area (ft^2)	Entry Velocity (fps)	Exit Velocity (fps)	Avg. Velocity Normal to Flow Path (fps) (4)	Volume (ft^3) (6)	Sxn Res. Time by Z/Vel$_{avg}$ (sec)	Sxn Res. Time by Vol/ACFM (sec)
1 (1)	0.000	224.000	224.000	274	274	348.44	521.36	11.07	7.40	8.93	0.0	0.00	0.00
2 (1)	0.000	274.000	274.000	274	274	521.36	521.36	7.40	7.40	7.40	0.0	0.00	0.00
3	203.125	274.000	274.000	274	274	521.36	521.36	7.40	7.40	7.40	8825.1	2.29	2.29
4 (5)	137.000	274.000	82.875	274	82.875	157.69	157.69	0.00	24.46	12.23	3600.7	0.93	0.93
5	49.750	121.000	82.875	121	82.875	69.64	69.64	55.39	55.39	55.39	288.7	0.07	0.07
6	37.823	121.000	82.875	121	82.875	69.64	69.64	55.39	55.39	57.23	212.5	0.06	0.06
7	18.000	121.000	82.875	121	82.875	69.64	69.64	55.39	55.39	55.39	104.5	0.03	0.03
Total:	60.50 ft									Total:	13031.4	3.38	3.38

Notes:

1. Sections 1 & 2 are only included in the WID residence time estimation if only 2 levels of overfire (OFA) or secondary air are installed and used for combustion air injection at all conditions. Sections 3 and higher are all completely downstream of the 3rd (last) level of overfire air.
2. Average Flow Path Length follows the path of the solid red line above.
3. The labels Length (L) and Width (W) of each rectangular flow cross section are the longest and shortest sides for horizontal planes and the horizontal and vertical sides, respectively, for vertical planes.
4. Except for Section 4, the Average Velocity is calculated from the integrated form of the average crosss-sectional area and a factor to convert to the velocity normal to the flow path (when needed): $Vel_{avg} = [Flowrate / (Lin*Win/3 + Lout*Win/6 + Lin*Wout/6 + Lout*Wout/3)]*Z/H$, where H is the perpendicular distance between the two parallel entry and exit planes of the section.
5. Section 4 is treated like a manifold with gas flowrate and velocity increasing linearly from left to right. The average gas velocity and average flow path length travelled by the gas in this section are used to calculate residence time by the Z/Vel$_{avg}$ method.
6. Section volume is calculated using the general equation for the volume formed by any two parallel rectangles with their vertices connected: $Volume = H/3*[Lin*Win + Lout*Wout + (Lin*Wout + Lout*Win)/2]$, where H is the perpendicular distance between the two rectangles
7. The gas flowing through these sections is above an average of 850 C (1,562 F).

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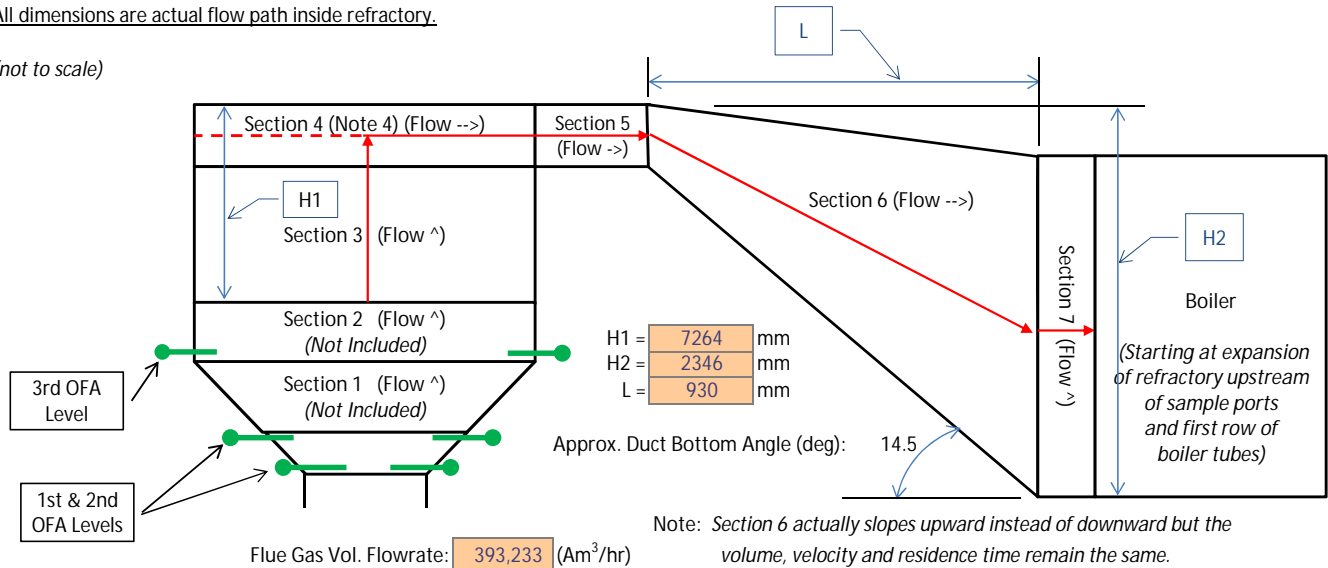Date: 6/17/2016   By: T.Kast
Revision: Rev. 0

All dimensions are actual flow path inside refractory.

(not to scale)

H1 = 7264 mm
H2 = 2346 mm
L = 930 mm

Approx. Duct Bottom Angle (deg): 14.5

Flue Gas Vol. Flowrate: 393,233 (Am³/hr)

Note: *Section 6 actually slopes upward instead of downward but the volume, velocity and residence time remain the same.*

Section (Note)	Avg. Flow Path Length, Z (mm) (2)	Entry X-sect. L (mm) (3)	Entry X-sect. W (mm) (3)	Exit X-sect. L (mm)	Exit X-sect. W (mm)	Entry X-sect. Area (m²)	Exit X-sect. Area (m²)	Entry Velocity (m/s)	Exit Velocity (m/s)	Avg. Velocity Normal to Flow Path (m/s) (4)	Volume (m³) (6)	Sxn Res. Time by Z/Vel_avg (sec)	Sxn Res. Time by Vol/Flow (sec)
1 (1)	0	5690	5690	6960	6960	32.37	48.44	3.37	2.26	2.72	0.00	0.00	0.00
2 (1)	0	6960	6960	6960	6960	48.44	48.44	2.26	2.26	2.26	0.00	0.00	0.00
3	5159	6960	6960	6960	6960	48.44	48.44	2.26	2.26	2.26	249.90	2.29	2.29
4 (5)	3480	6960	2105	6960	2105	14.65	14.65	0.00	7.46	3.73	101.96	0.93	0.93
5	1264	3073	2105	3073	2105	6.47	6.47	16.88	16.88	16.88	8.18	0.07	0.07
6	961	3073	2105	3073	2105	6.47	6.47	16.88	16.88	17.44	6.02	0.06	0.06
7	457	3073	2105	3073	2105	6.47	6.47	16.88	16.88	16.88	2.96	0.03	0.03
Total:	18.44 m									Total:	369.01	3.38	3.38

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