TEST CASE 2: FCC RISER

Summary

This case concerns riser flow with FCC catalyst. The riser is 0.311m id and 15 m long. Air flow is 0.625 kg/s, corresponding to 5-6m/s and the catalyst mass flux is 146 kg/s/m2 in ambient conditions. Downstream pressure is about 114 450 Pa (absolute Pressure)

Calculation Request

- Pressure profiles along the riser
- Profiles of net mass flux along the riser diameter 1.325 m and 7m above inlet.

Information

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Experimental Set up

The riser on which measurement was conducted is a 311mm stainless steel id. tube. It is inserted in a circulating fluidised bed loop containing several fluidised beds. The main features of the unit, useful for the riser simulation are reported on figure 1, 2 and 3. Figure 1 shows the general layout of the riser. Catalyst is introduced laterally at the riser bottom. Air is introduced axially through a center pipe. The flow then develops along about 15m up to a ballistic separator abruptly ending the riser. Gas and particles discharge in the dilute phase of a fluidised bed. Catalyst settles in the dilute phase down to the fluidised bed and dusty air flows upward toward cyclones located outside the fluidised bed. Catalyst flows from the fluidised bed though other vessels and is then recycled back at the riser bottom.

More details upon the riser bottom are found on fig.2. Catalyst flows to the riser through a 132mm-id standpipe in a dense phase with a typical apparent density of 600-800 kg/m^3. A diaphragm valve at the standpipe bottom enables to control the flow of catalyst fed to the riser by adjusting diaphragm opening. Below the valve, catalyst flows through a 200mm long vertical section and an 800 mm-inclined part (45° to vertical). Catalyst is then introduced laterally to the riser, around the center pipe providing most of the air. The main air flow rate is introduced through the center pipe (103 mm id, 5mm thickness) Additional aeration is provided around the center pipe (secondary air flow), introduced through a porous plate material extending over the riser cross section.
The reference elevation for all results is taken as the upper position of the center pipe in the riser (see fig.1)

The riser top geometry is described on fig.3. At the riser top, all the flow is divided into four horizontal pipes (250 mm id). with 225mm openings to discharge the whole gas-particle flow downwardly in the dilute phase.

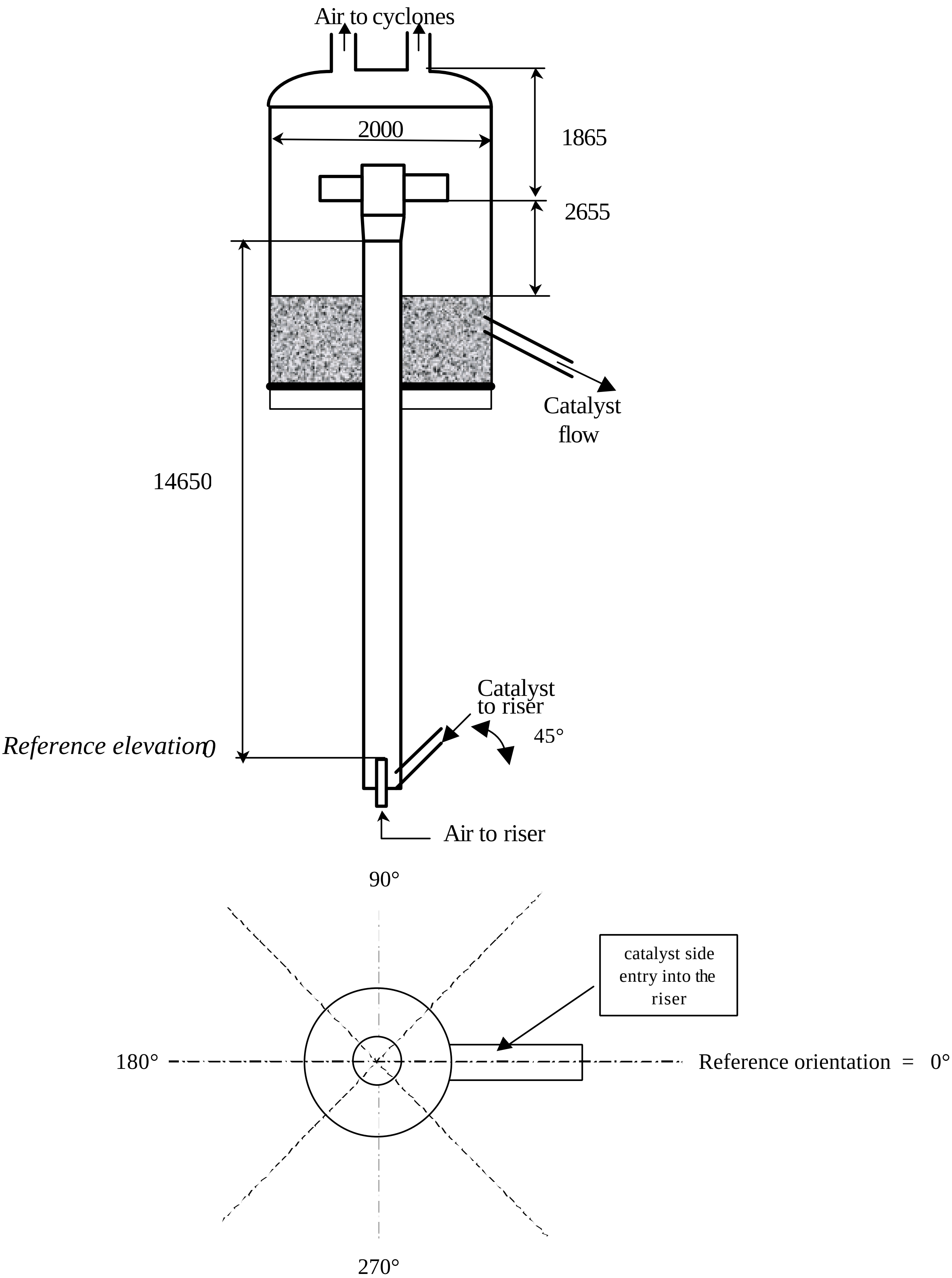


Figure 1 : CFB geometry (dimension in mm)

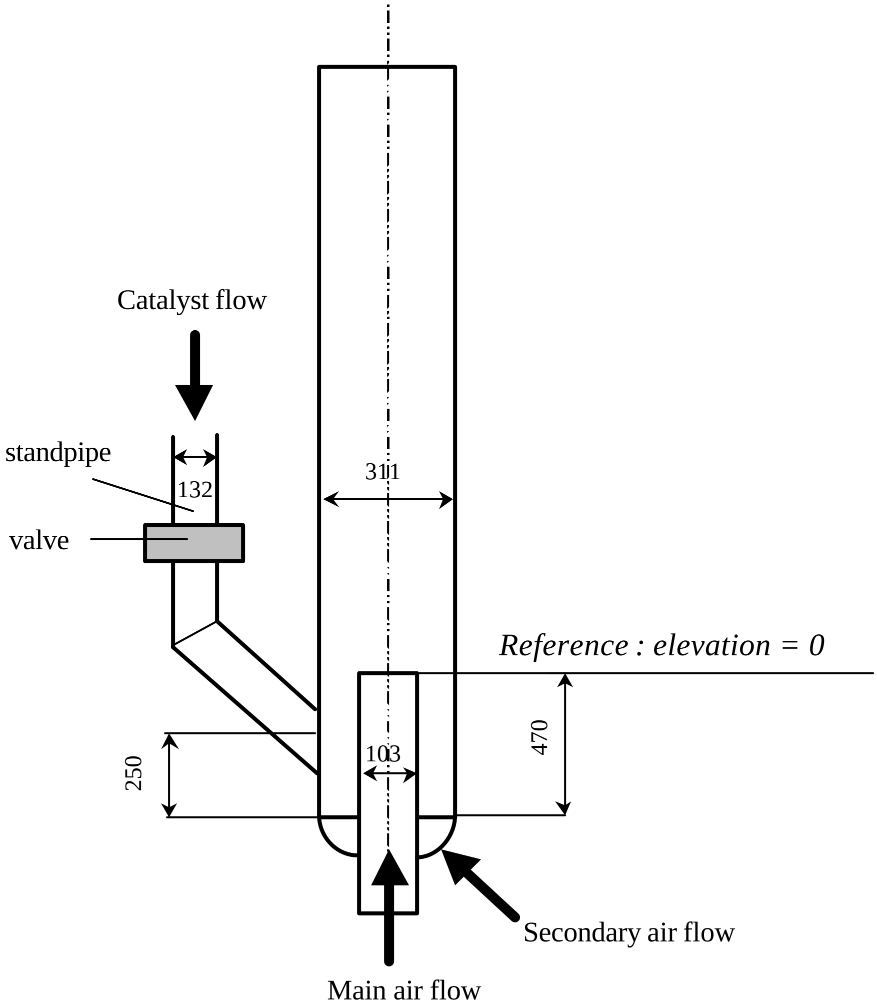


Figure 2: Riser Bottom Geometry (dimension in mm)

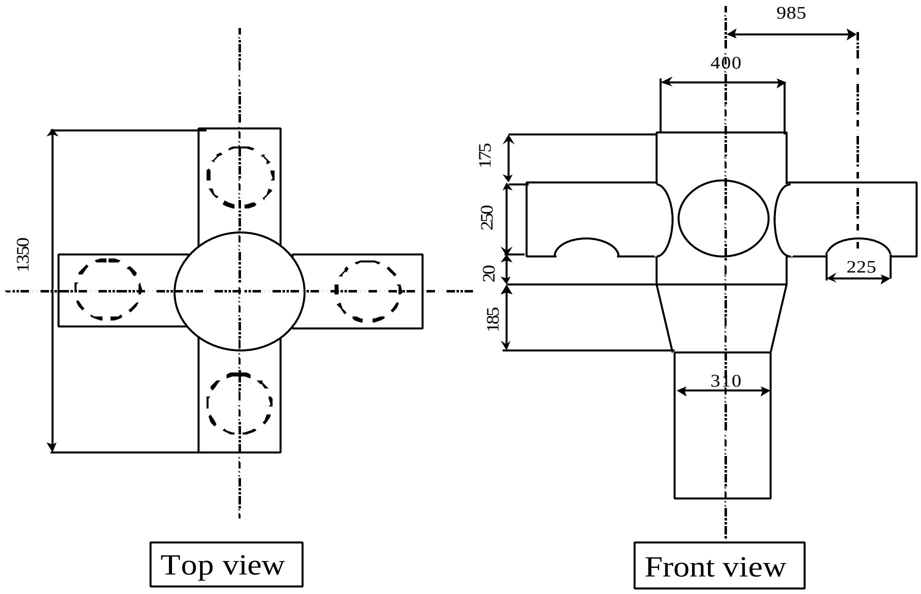


Figure 3 : Riser ballistic separator geometry (dimension in mm)

Operating Conditions

In the conditions of the present case, the following operating conditions were applied

Riser gas flow:
Compressed air is introduced in the riser through the central pipe. Air flow is controlled by valves and measured with "Annubar» flow-meters. The air flow through the central pipe is 0.6247 kg/s.

Secondary air is introduced around the central pipe to maintain good fluidisation conditions at the riser bottom. Secondary air flow, measured with a rotameter at a know pressure, is equal to 0.00162 kg/s.

Air humidity is about 60%-80% with an air temperature ranging 15-25°C (not controlled).

Riser outlet pressure:
During the test, riser outlet pressure, corresponding to the dilute phase pressure of the fluidised bed at the level of the riser discharge is constant and equal to 114450 Pa (Absolute pressure). This pressure is fixed by downstream flow conditions (cyclones, filter and valve), which are essentially dependant upon gas flow, which is kept constant.

Fluidised bed dilute phase flow rate :
Gas and catalyst from the riser discharge in the dilute phase of the fluidised bed and mix with the air fluidising the bed before recycle. This air flow rate is equal to 0.273 kg/s. This additional air flow, downstream, has no influence at all upon the riser flow upstream.

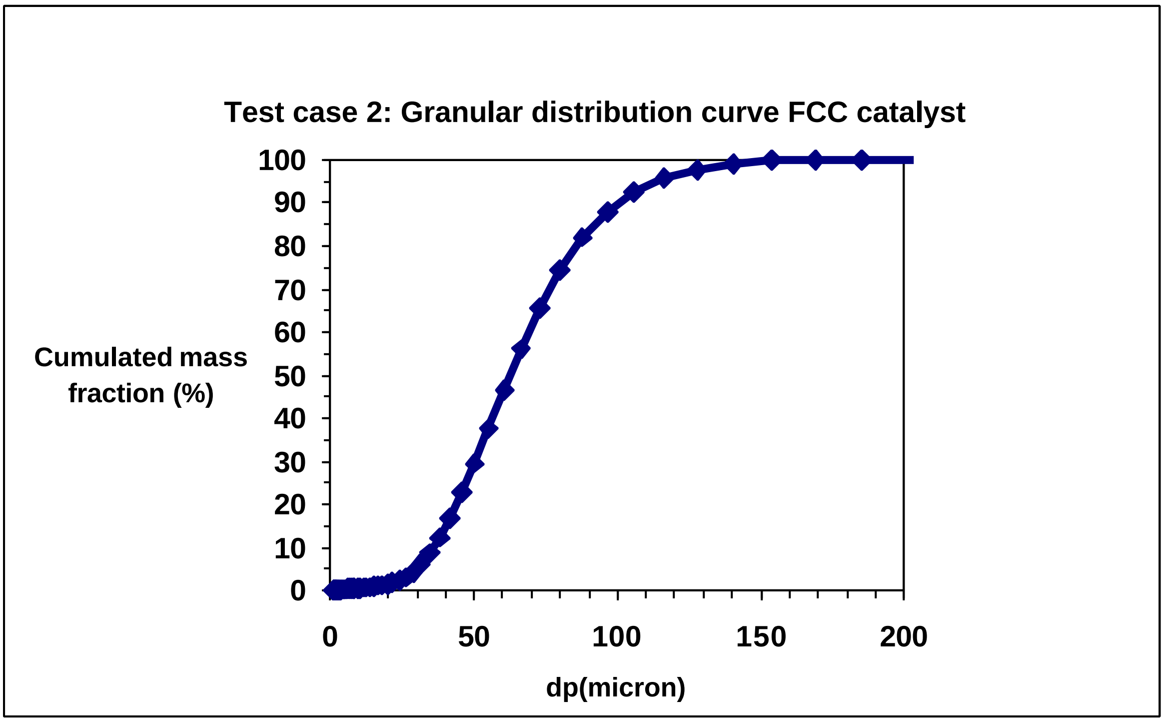
Catalyst Flow Rate:
Catalyst flow through the riser is dependant upon the flow control valve opening (see Fig.2). It is adjusted to obtain the riser pressure drop corresponding to requested catalyst flow rate. The relationship between riser pressure drop and catalyst flow rate at a given pressure and gas flow rate is obtained from a specific separate experiment: gas and catalyst flow through the riser but catalyst recycle from the fluidised bed on top of the riser is stopped and leads to bed level variations due to catalyst accumulation. The large catalyst inventory of the CFB (12 t) enables bed level variations of 1-2m of catalyst during 2 to 6 min, which is enough to accurately determine the catalyst flow rate within +/-10%
In the conditions of this test, catalyst flow through the riser was equal to 146 kg/s/m^2 +/-10%.

Run Conditions	
Outlet Pressure (Pa)	114450
Temperature (K)	293

Gas Phase: Air *			
r (kg/m3) *	1.36	QG mean (kg/s)	0.62470
μ (Pa.s)*	0.000018	QG secondary (kg/s)	0.00162

* Outlet conditions

Solid Phase: FCC catalyst			
dpsv / dp50(micron)	53.1 / 62.3	Rhos (kg/m3)	1600
j (-)	1.0	QS (kg/s)	11.0908
Size Distribution	See XLS sheet		



Experimental data

Two experimental data are reported :

- -pressure drop
- -radial mass flux profiles at two different elevations

Pressure drop measurements:

The pressure drop measurements were conducted with 13 Rosemount differential pressure transducers (calibrated and with appropriate range) connected to pressure taps at the riser wall (for pressure taps 1 to 12), and at the wall of the fluidised bed dilute phase for pressure tap 13). Table 1 gives the elevation of each pressure tap relative to the reference elevation, corresponding to the upper position of the central pipe into the riser (see fig.1). The first twelve transducers used measure differential pressures in between two consecutive pressure taps and the thirteenth transducer used measures the overall riser pressure drop in between pressure tap 1 and 13. Each measurement is validated only if the sum of consecutive pressure drops equals the overall riser pressure drop within 2 %.An additional pressure transducer connected at pressure tap 13 measures the absolute pressure at the wall of the dilute phase. Porous material, flush with the riser wall, is inserted in each tap to avoid any particle accumulation in the taps. Those porous materials are regularly checked versus plugging problems and changed. Data acquisition collects the time series at 1 Hz during 400 s, once the flow has been steadily established during at least 15 min .All the information can then be used to determine axial pressure profile along the riser at the elevation given on table 1.

Pressure tap Number	**Elevation (m)**	**Orientation (°) (see fig.1)**
1	0.120	180
2	0.770	190
3	1.130	45
4	1.455	335
5	2.120	335
6	3.115	335
7	3.785	90
8	5.455	45
9	6.110	80
10	7.455	55
11	8.120	80
12	10.110	80

Table 1 : Pressure tap elevation and orientation along the riser wall

Note: Pressure tap 13 is located 16.165m above the reference elevation at the wall of the fluidised bed It is used to measure the dilute phase absolute pressure in the fluidised bed and pressure drop due to riser top above tap 12, between taps 12 and 13.

Radial mass flux profiles:

The local mass flux of catalyst in the riser was estimated with a sampling suction probe inserted inside the riser. The probe geometry is shown on figure 4. It consists of the bended tube (8mm I.D, 10mm O.D) . This tube can be moved in order to sample catalyst at several radial positions all along a riser diameter. Furthermore, it can be inserted with the opening directed downward (facing the flow) to sample catalyst flowing in the upward direction or inserted with the opening directed upward to sample catalyst flowing in the downward direction. Figure 5 shows the sampling line system used during the present study. The sampling probe is connected to a filter which collects all particles flowing through the suction probe. Clean gas flowing out of the filter flows through a rotameter and to a vacuum cleaner system. A valve located downstream the rotameter (3) leads to control gas flow sucked with particles through the probe. Air can be introduced in (1) to clean up the lines whenever required. The filter is weighted before and after each experiment in order to determine the amount of particles collected.

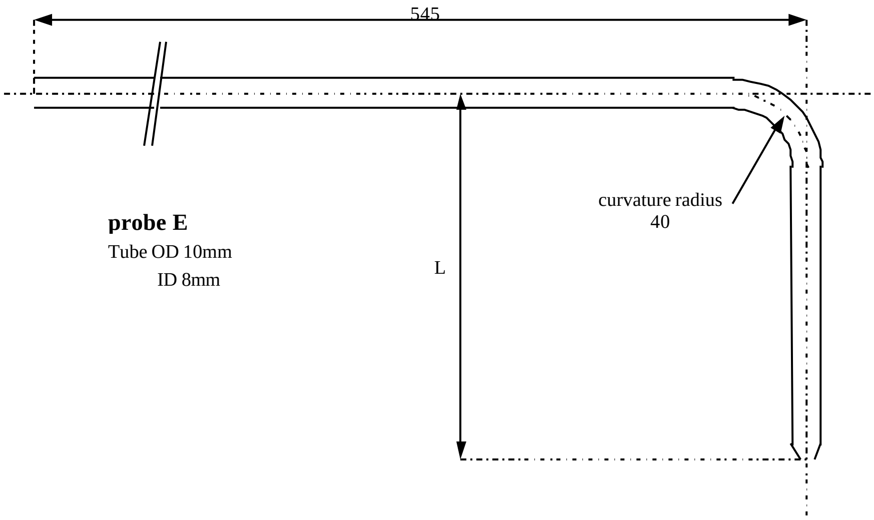


Figure 4: Sampling suction probe used to measure local solid mass fluxes (dimension in mm)

At each sampling location, catalyst was sampled during 2 min to obtain a flow rate of particles independent of the sampling time. The suction gas in the probe was kept constant and equal to the superficial velocity in the riser. The net local solid mass flux, corresponding to the difference of the upward and downward mass fluxes at a given location was found to be independent upon the suction gas velocity.

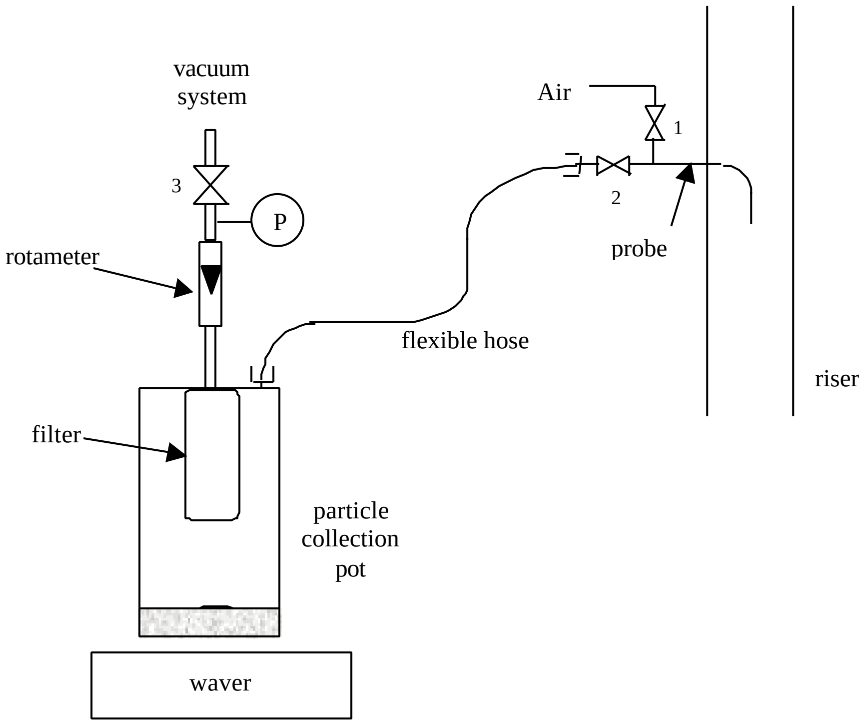


Figure 5: Sampling line to collect sucked particles

Local solid mass fluxes profiles were measured at two elevations relative to the reference elevation (see fig.1) At elevation 1325mm, upward flux was measured through a tap at elevation 1525 mm and downward flux at elevation 1125mm in order to get the probe opening at the same elevation 1325mm. At 7000mm, the same tap was used (inducing a 400mm difference between the opening of the probe for the downward flux, i.e. 7200mm, and for the upward flux, i.e. 6800mm; this difference is considered as non significant for the net mass flux determination 7000mm above the riser inlet). For each profile, the radial locations included in table 3 were investigated. The probe geometry does not allow for sampling close to the tap. At 7000mm, profiles were obtained along the same orientation with probe insertion either from one side or the other (orientation 0° and 180° on table 3) and similar results were obtained. The orientation reference angle related to catalyst entry is shown on fig.1.

Elevation (mm)	1325	7000	7000
Orientation (°) **See fig.2**	215° **r/R(-)**	0° **r/R(-)**	180° **r/R(-)**
	-0.828	-0.828	-0.828
	-0.749	-0.749	-0.749
	-0.660	-0.660	-0.660
	-0.556	-0.556	-0.556
	-0.427	-0.427	-0.427
	-0.177	-0.177	-0.177
	0.000	0.000	0.000
	0.177	0.177	0.177
	0.427	0.427	0.427
	0.556	0.556	0.556
	0.660	0.660	0.660
	0.749	0.749	0.749
	0.828	0.828	0.828
	0.901	0.901	0.901
	0.968	0.968	0.968

Table 2: Sampling elevations and radial positions

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