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CDTN

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Comissão Nacional de Energia Nuclear

A TRACER APPLICATION: DETECTING DAMAGE TO OIL INDUSTRY PIPING

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The problem to be attacked

- Massive investments by the oil industry are directed to maintenance and inspection.
- Annual cost of corrosion to the oil and gas industry in the United States alone estimated to be $27 billion, leading to an estimate of the global annual cost of maintenance as exceeding $60 billion

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Main aims of maintenance

- Avoid breaches in the production process.
- Maximum advantage of time, personnel and tool resources obtained during planned pauses for maintenance.
- Avoid large negative impacts on economic achievement.

To comply with this:

- Equipment inspection procedures on a continuing basis emerge as crucial.

- The search for new inspection techniques turned into a differential in the oil industry.

Hence, some conjectures:

- Could tracers also be of value in detecting internal damage to closed pipes subject to aggressive environments such as oil processing plants?

- Could they be added to the present roll of nondestructive inspection techniques?

Corrosion and Scaling

- Two of the most deleterious damages to the structural properties of equipment components in oil refineries.
- Requiring unpostponable intervention and production stoppage.

Corrosion and Scaling

- Despite progresses have been achieved in the scientific knowledge of these processes, problems persist.
- They may even become more severe, due to the heavier, and therefore more acidic, crude oils being introduced in the refining processes.

Pit corrosion

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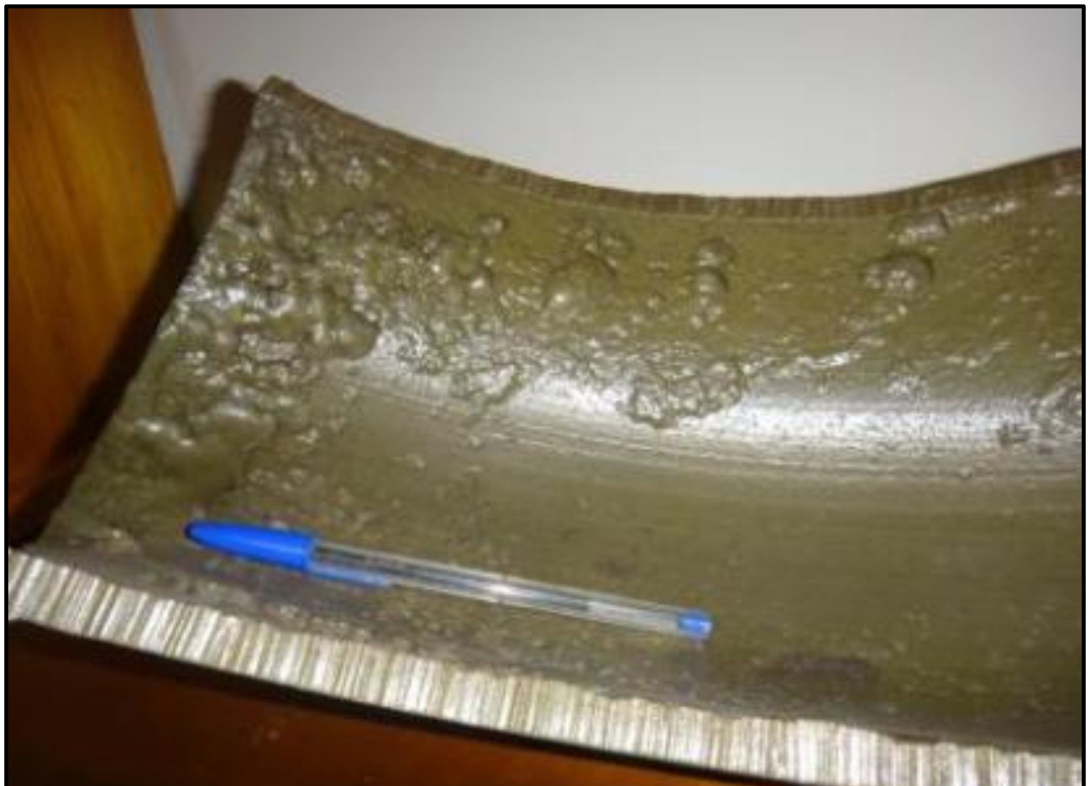
Pit corrosion

- Internal aspect:



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Pit corrosion

(50 X)

Scaling

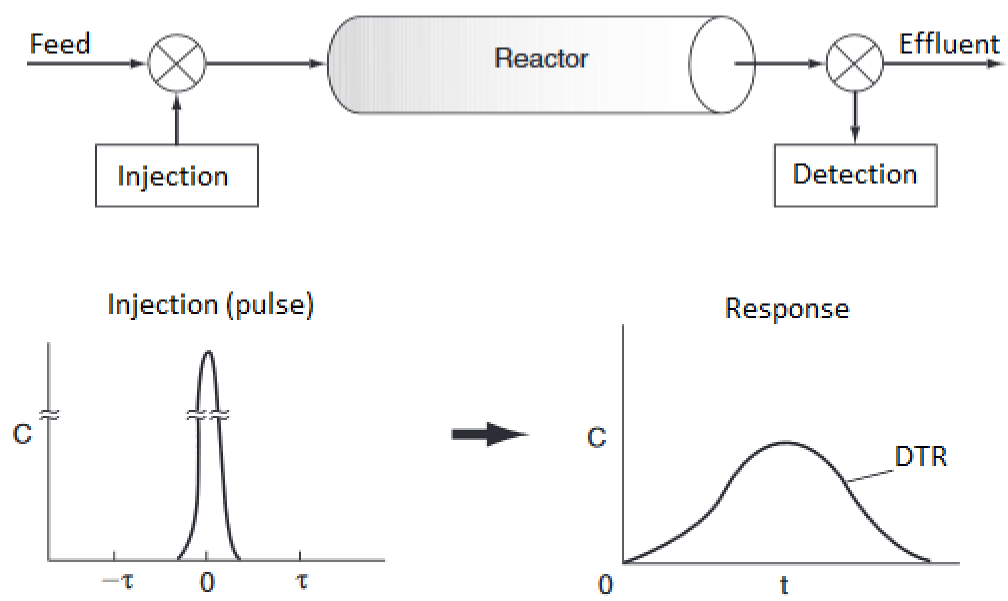
- Iron hydroxide scales:

Scaling

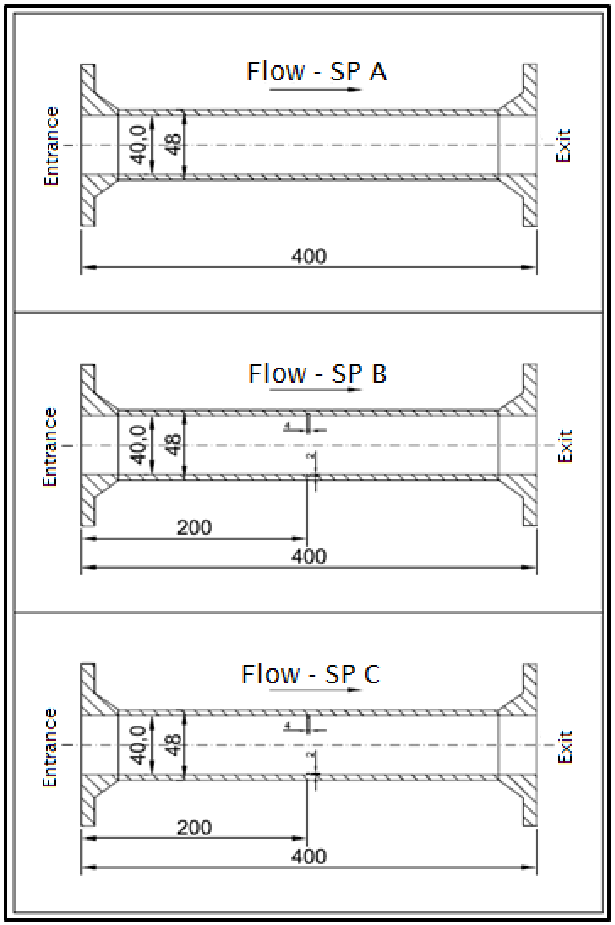
- Scaling at a cooling water pipe

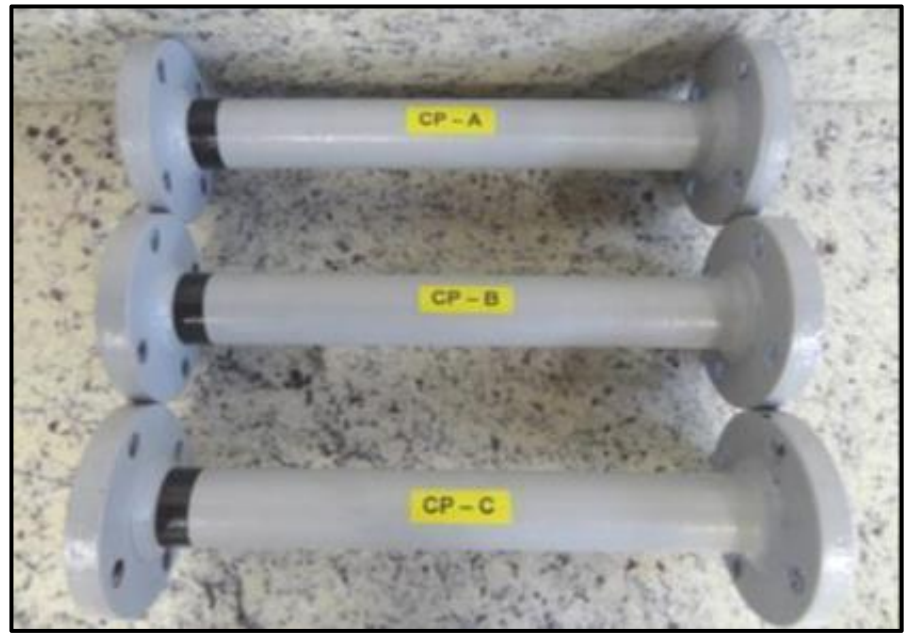
Methodology: Tracer impulse response

- Residence time distribution: $E(t) = \frac{C(t)}{\int_0^T C(t)dt}$
- Mean residence time: $\bar{t} = \int_0^T t.E(t)dt = \frac{V}{Q}$



Simulacra pieces





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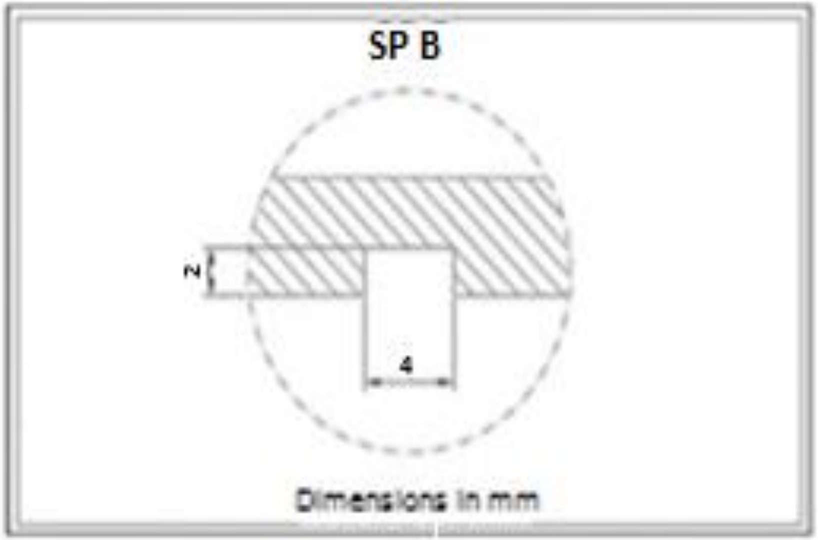
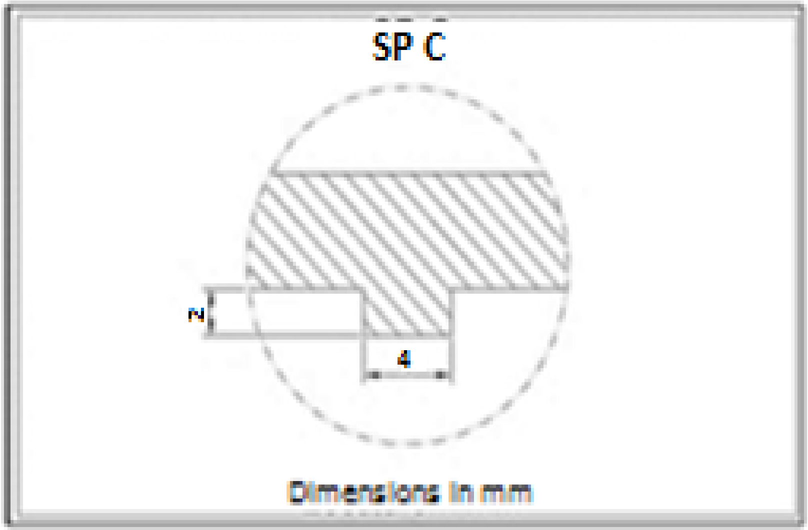
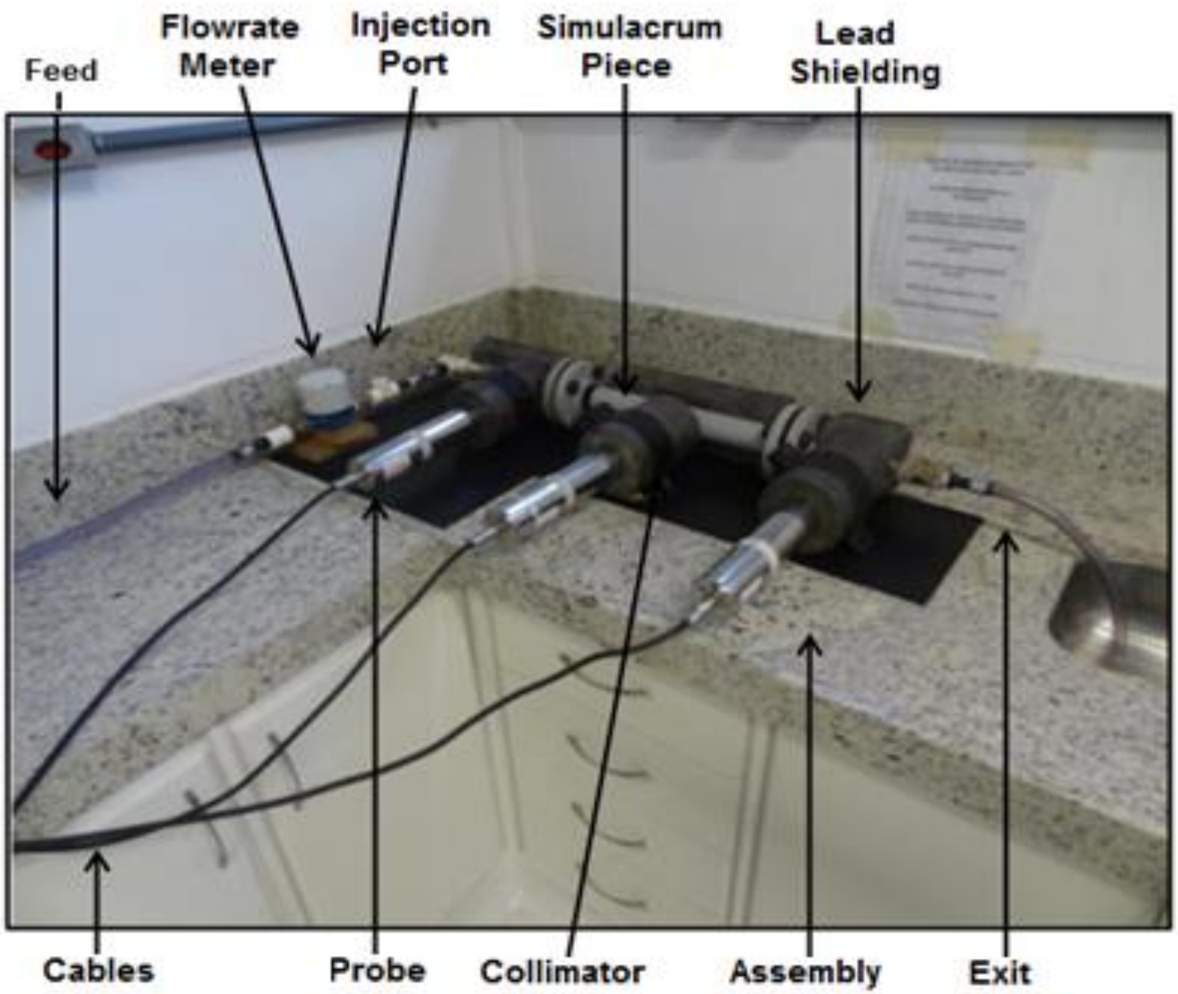
Simulacra pieces

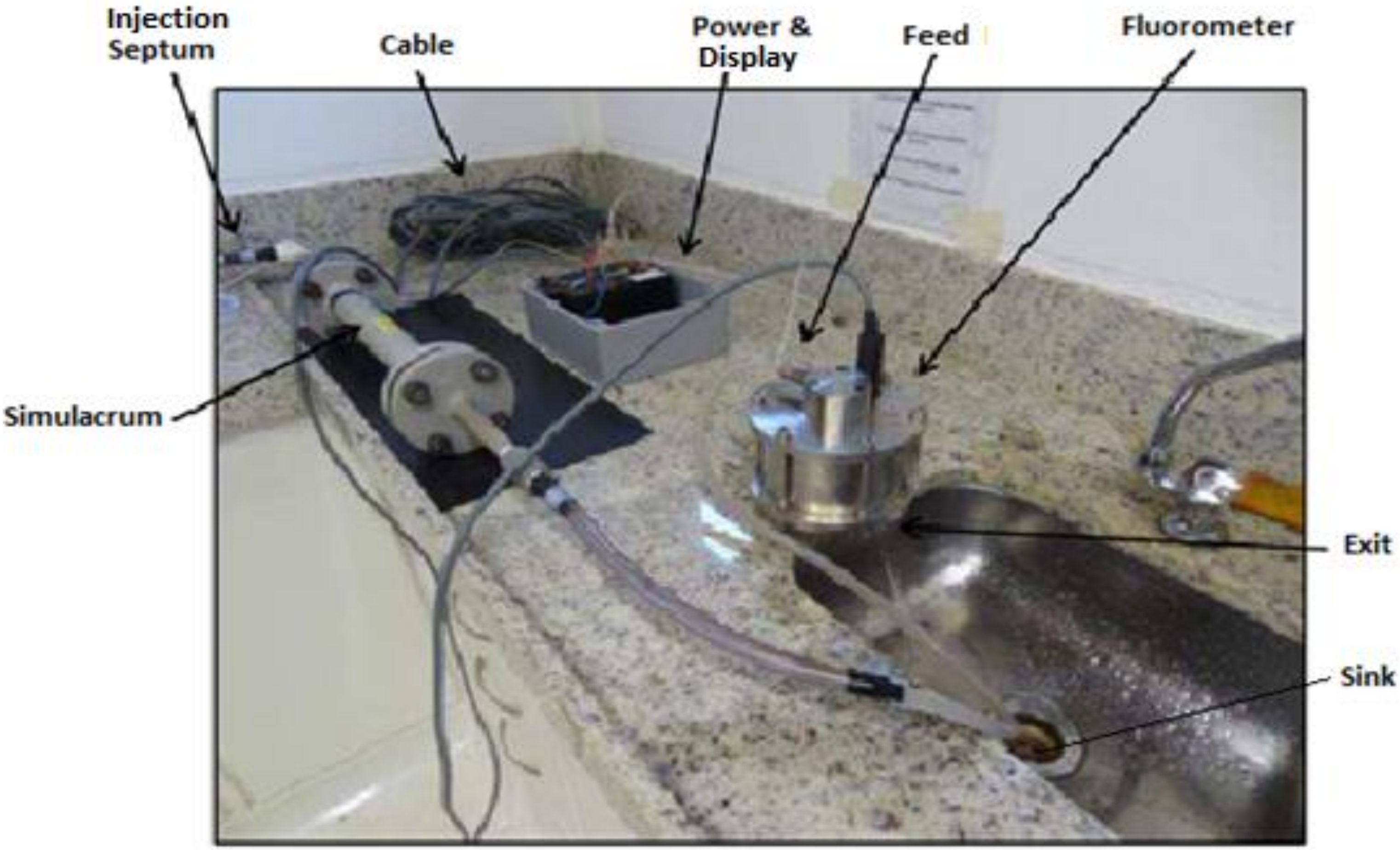


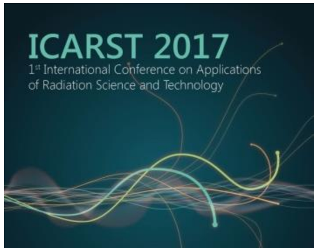


Assembly for Radiotracer test



Assembly for Dye Tracer test



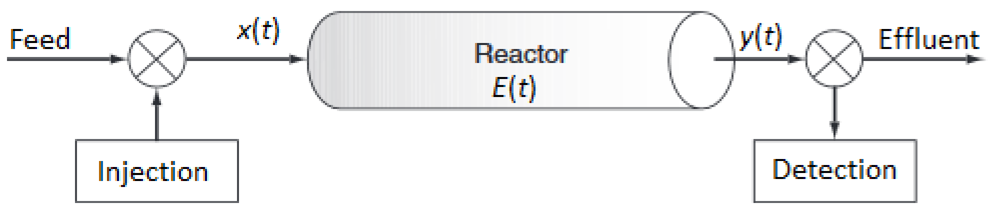


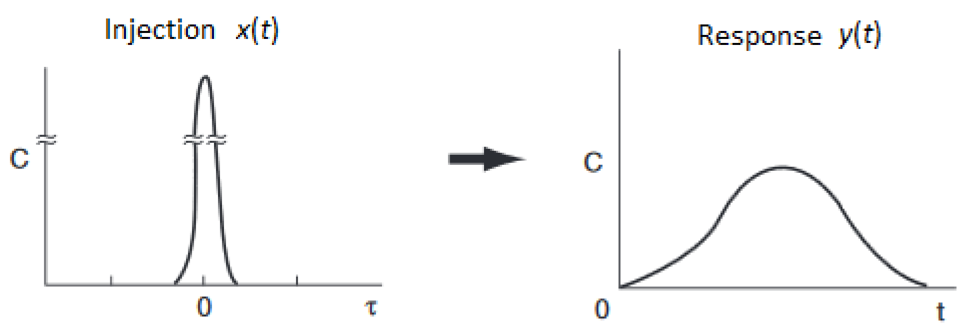
GGUN-FL Fluorometer

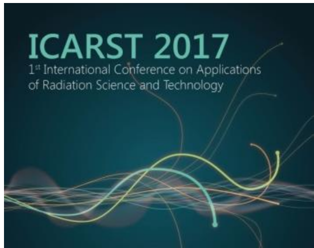
DTS-Pro Software

- Convolution of entrance and exit pulses

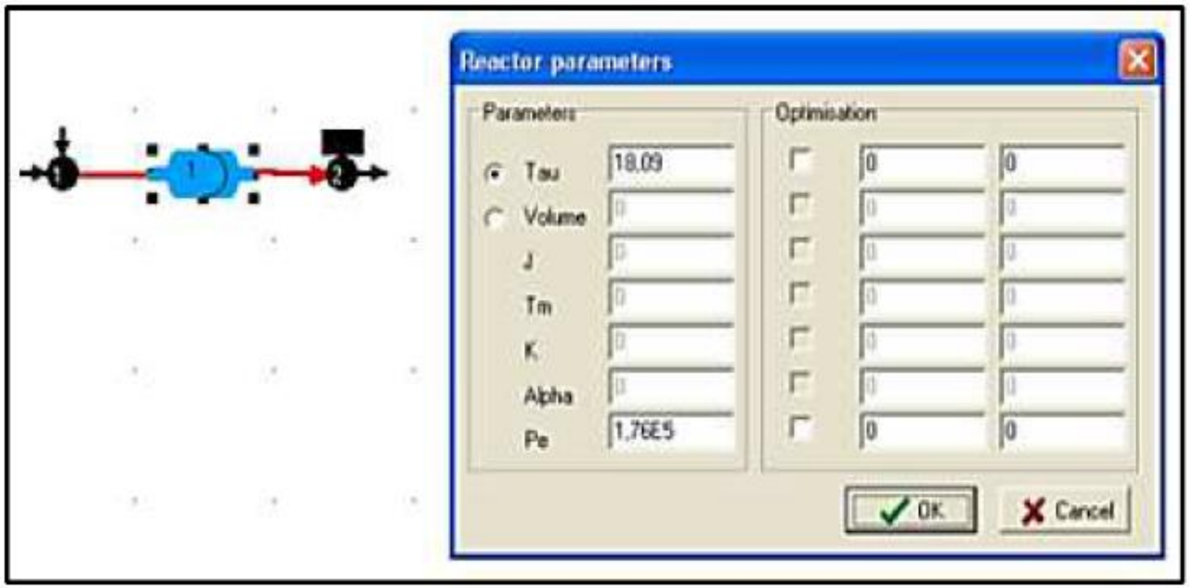
$$y(t) = \int_0^t E(t').x(t-t')\,dt'$$







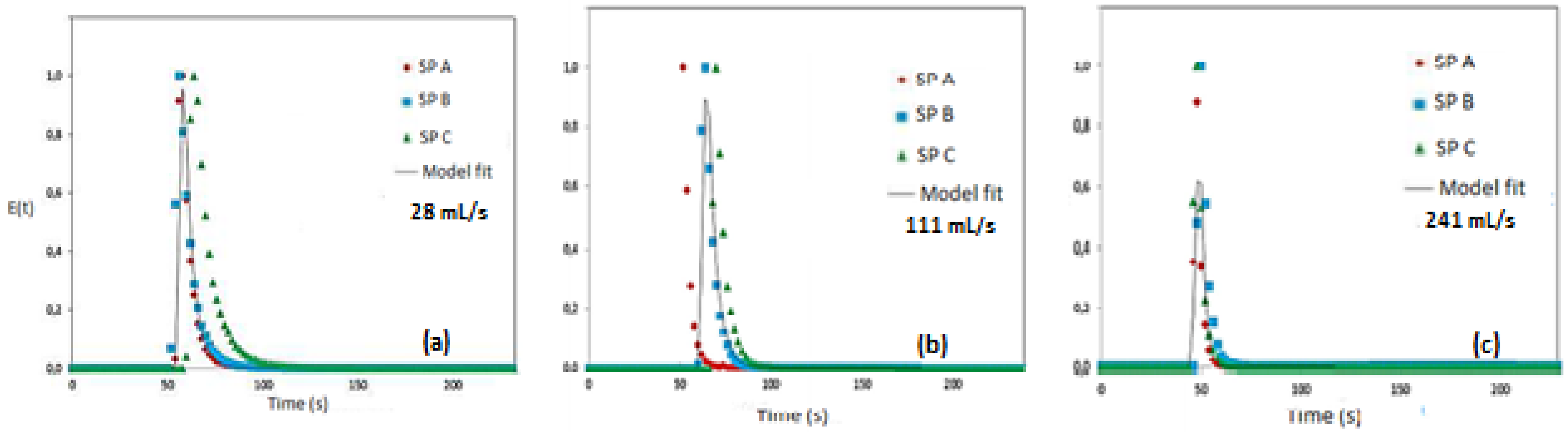
DTS-Pro Software



Test flowrates

Identification	Flowrate ($mL.s^{-1}$)	Reynolds Number	Flow regime
Q1	28	880	laminar
Q2	111	3519	turbulent
Q3	249	7918	turbulent

Results from dye tracer tests

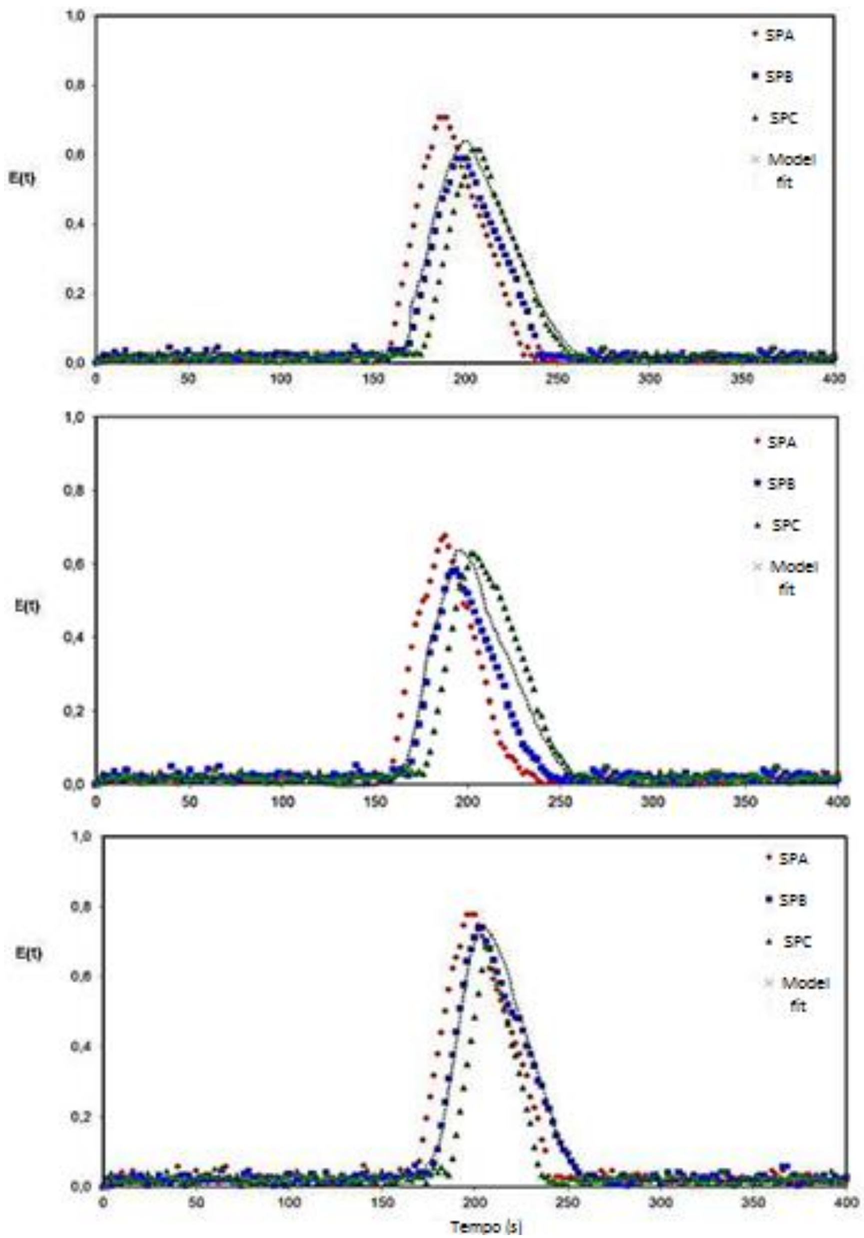


Results from radiotracer tests
Entrance Probe

28 mL/s (laminar)

111 mL/s (turbulent)

249 mL/s (turbulent)



SP A – clean

SP B – pit

SP C – scale

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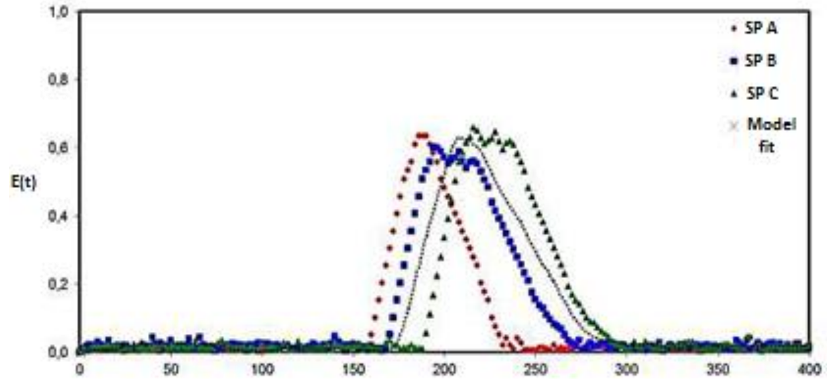
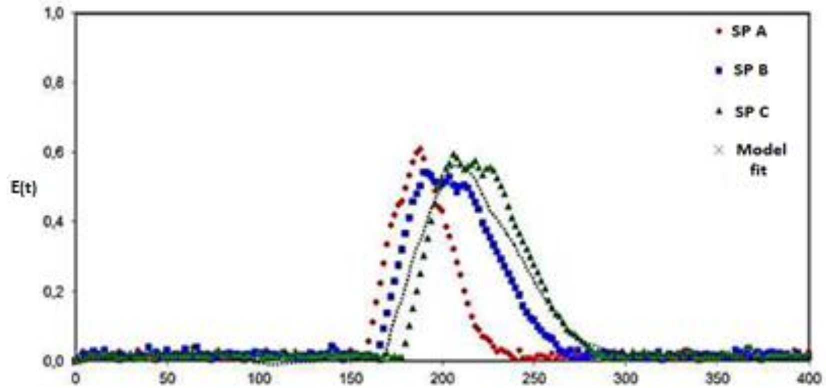
Results from radiotracer tests
Middle Probe

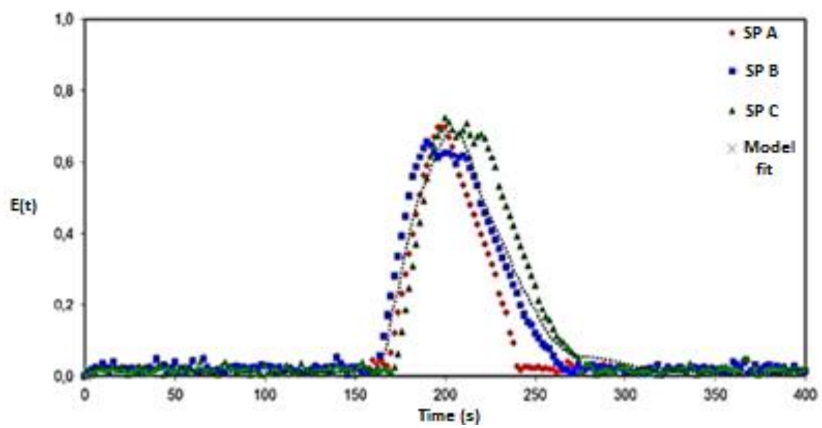
28 mL/s
(laminar)



111 mL/s
(turbulent)



249 mL/s
(turbulent)



SP A – clean

SP B – pit

SP C – scale

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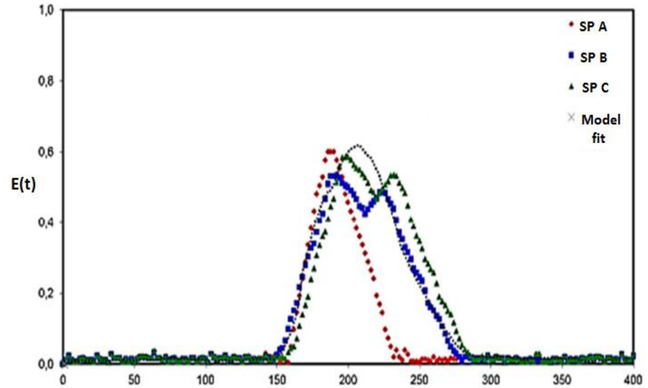
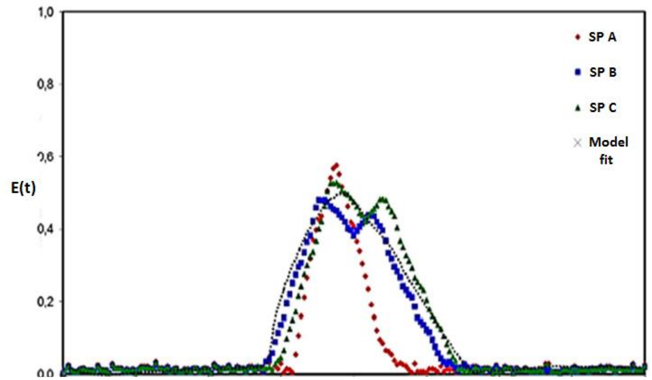
Results from radiotracer tests
End Probe

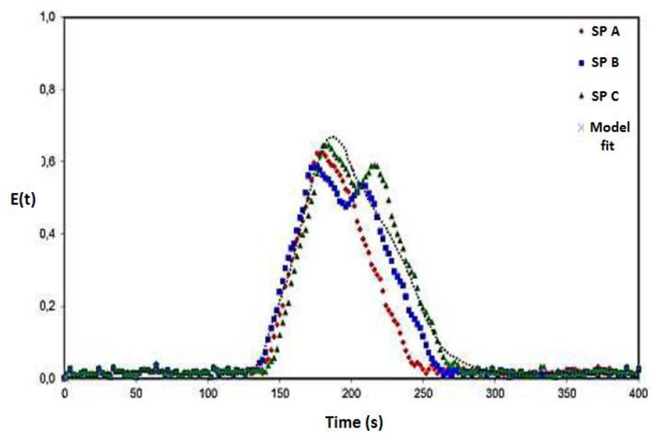
28 mL/s (laminar)



111 mL/s (turbulent)



249 mL/s (turbulent)

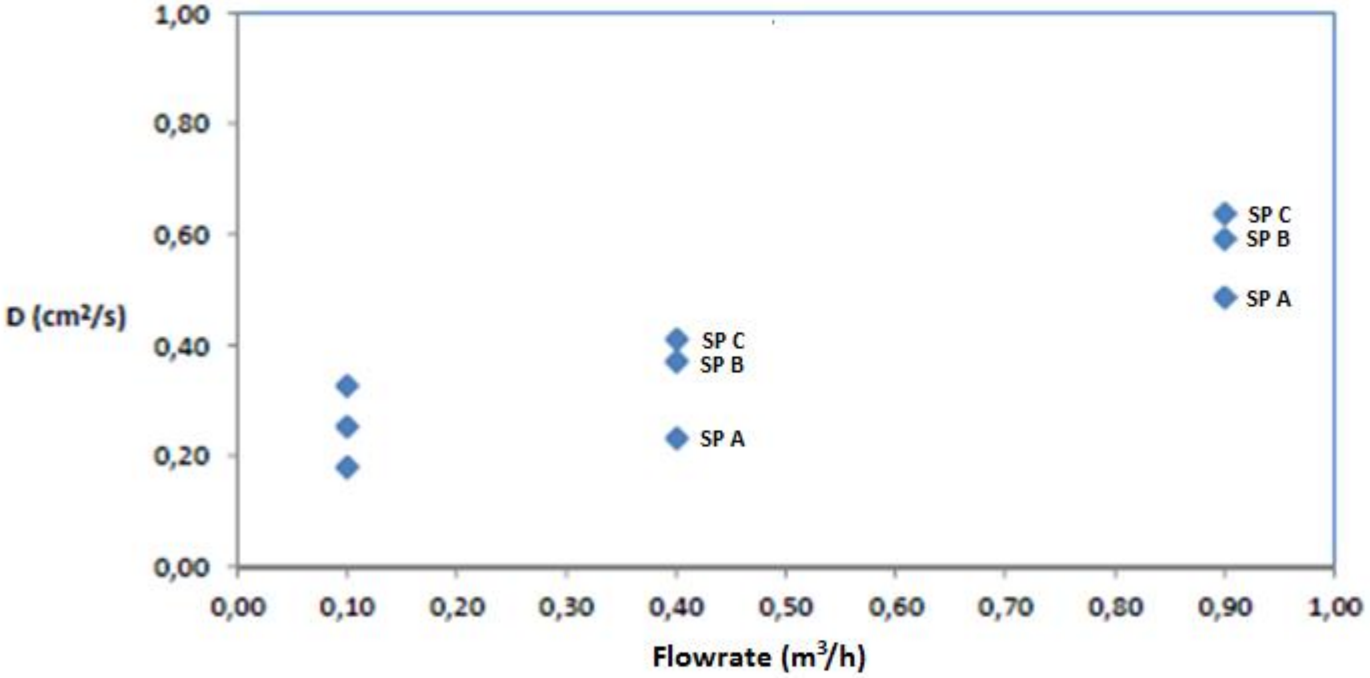


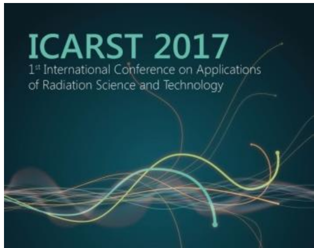
SP A – clean

SP B – pit

SP C – scale

Dispersion coefficients

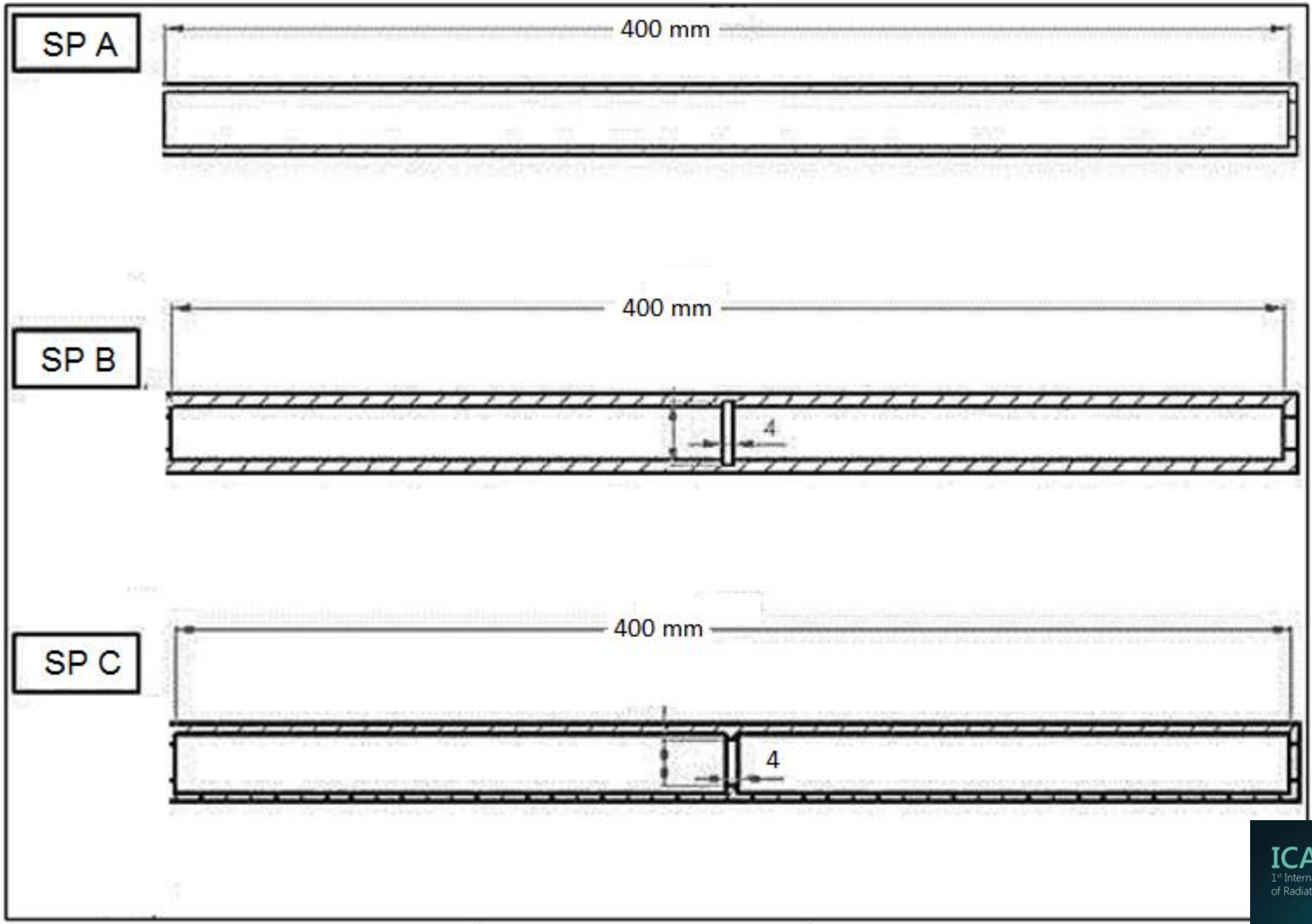




Flow parameters calculated by DTS Pro

SP	Flowrate (mL/s)	$\bar{t}$ (s)	V (cm/s)	D (cm^2/s)	Pe
	28	18,09	2,21	0,181	$1,76 \times 10^5$
A	111	4,68	8,55	0,233	$5,46 \times 10^5$
	249	2,16	18,52	0,488	$5,87 \times 10^5$
	28	20,17	1,98	0,254	$1,25 \times 10^5$
B	111	6,25	6,40	0,371	$3,43 \times 10^5$
	249	3,42	11,69	0,592	$4,84 \times 10^5$
	28	23,71	1,68	0,327	$0,97 \times 10^5$
C	111	7,24	5,52	0,412	$3,09 \times 10^5$
	249	5,83	6,86	0,638	$4,49 \times 10^5$

CFD Simulation - Geometry



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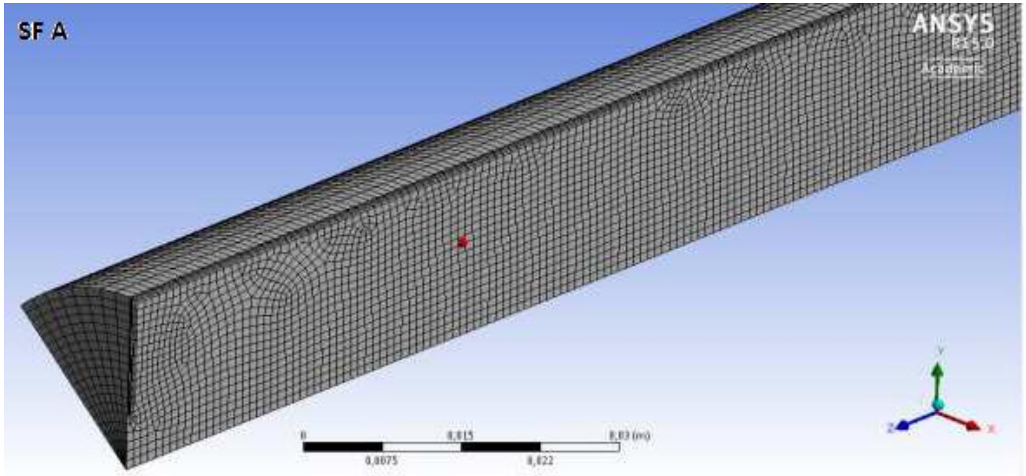
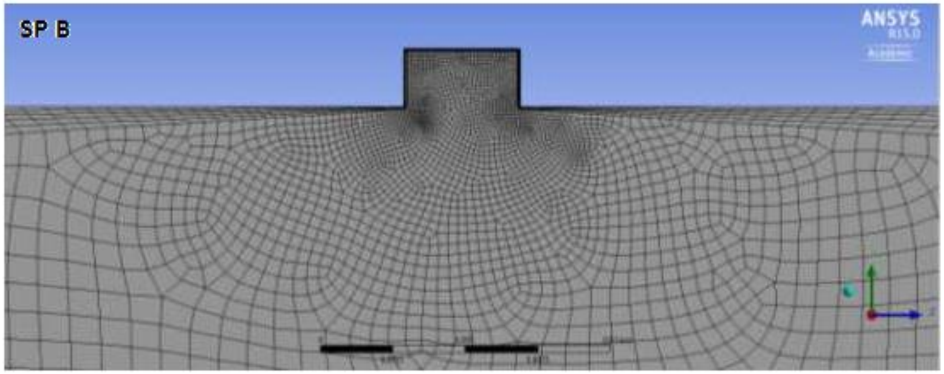
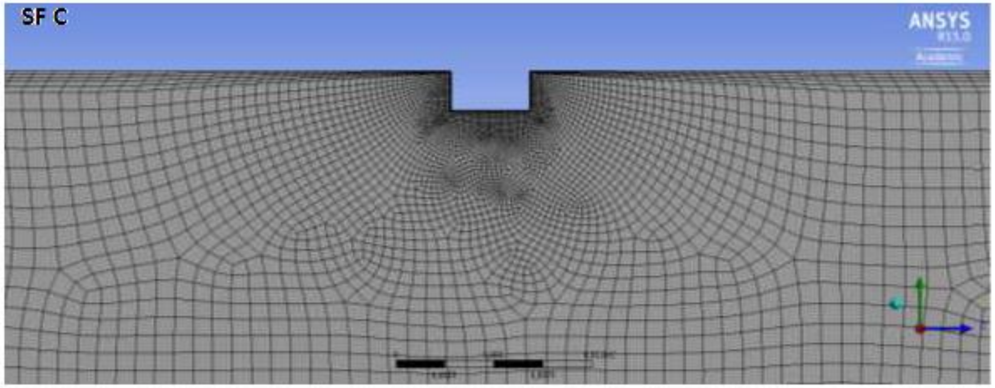
CFD Simulation – Boundary conditions

Material	Mass flowrate (kg/s)	Reynolds Number	Feed pressure (atm)	Domain
	0,028	880,074		
Pure water (constant properties)	0,111	3519,757	1,000	Insode tube volume
	0,249	7918,049		

CFD Simulation – 3D Grid

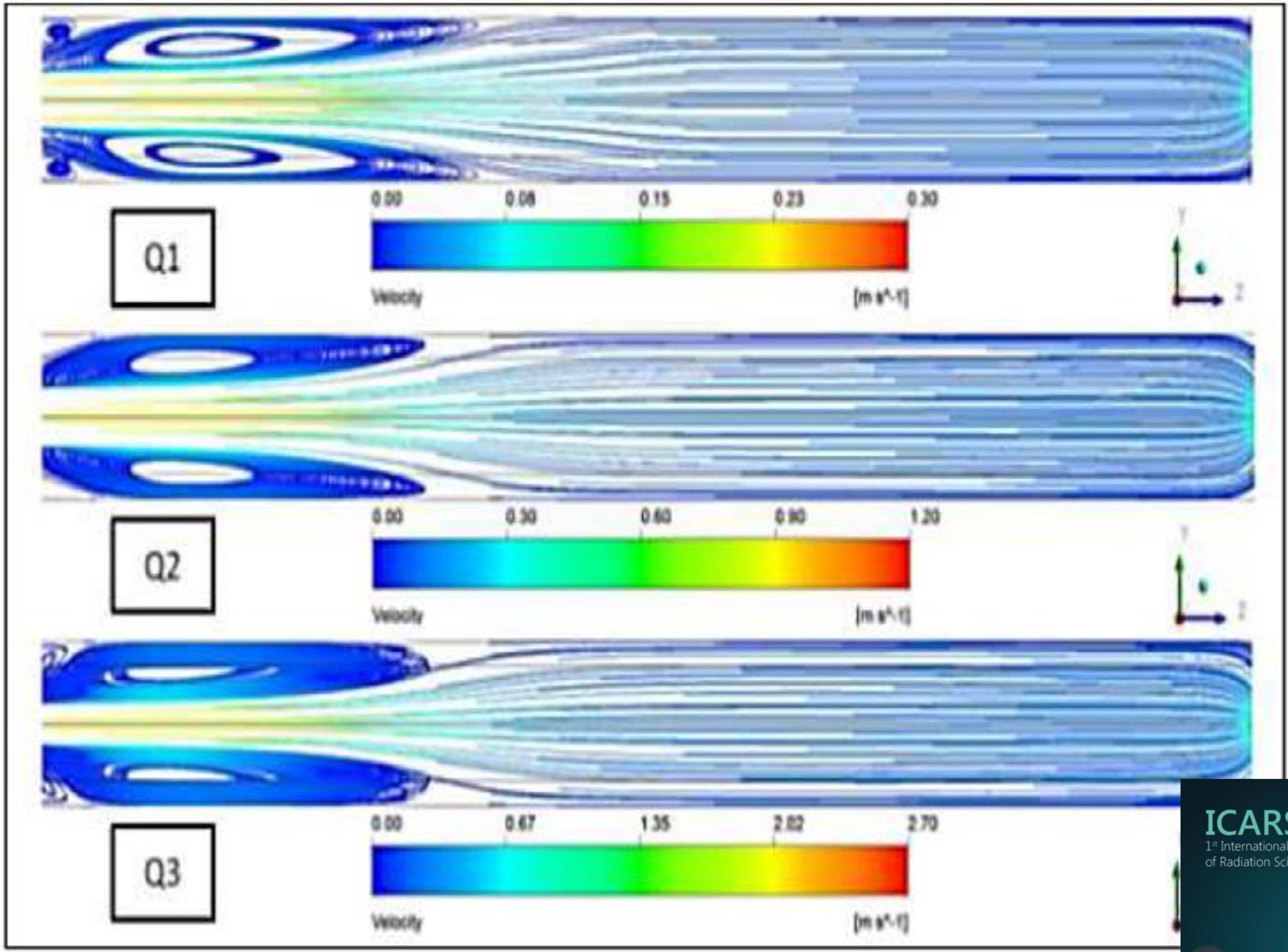






CFD Simulation Results – Streamlines

SP A



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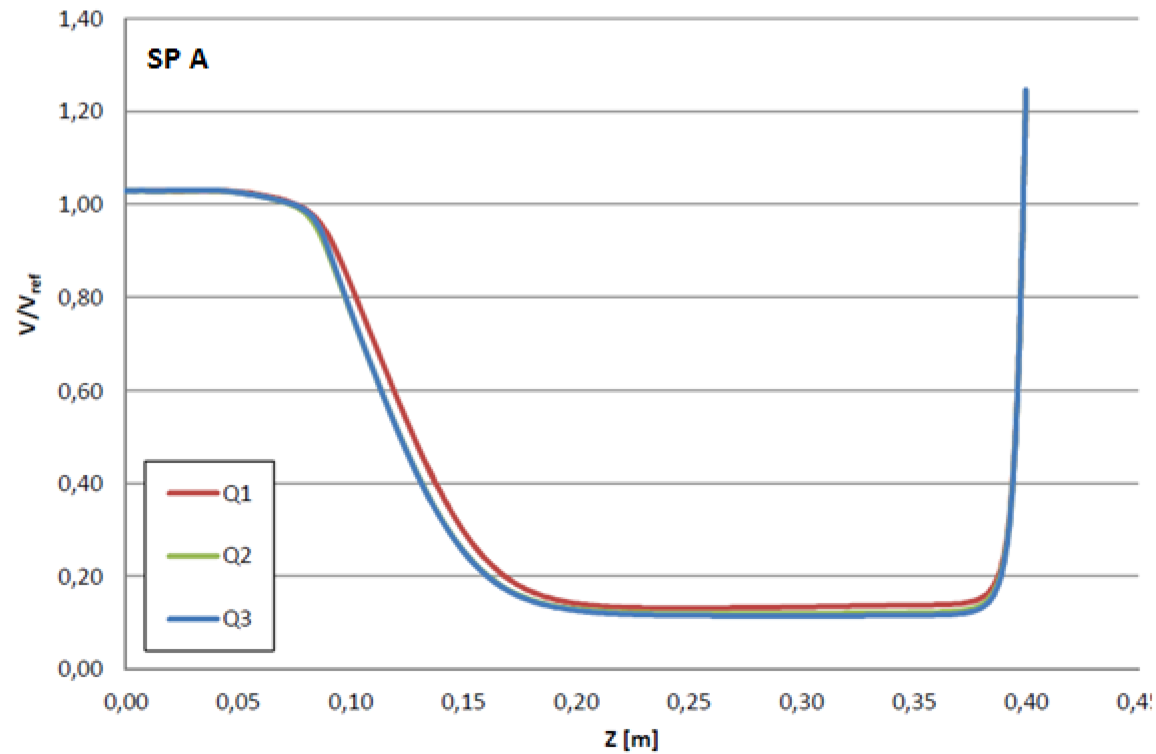
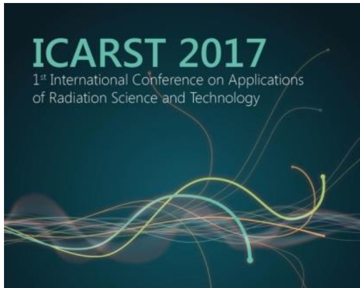
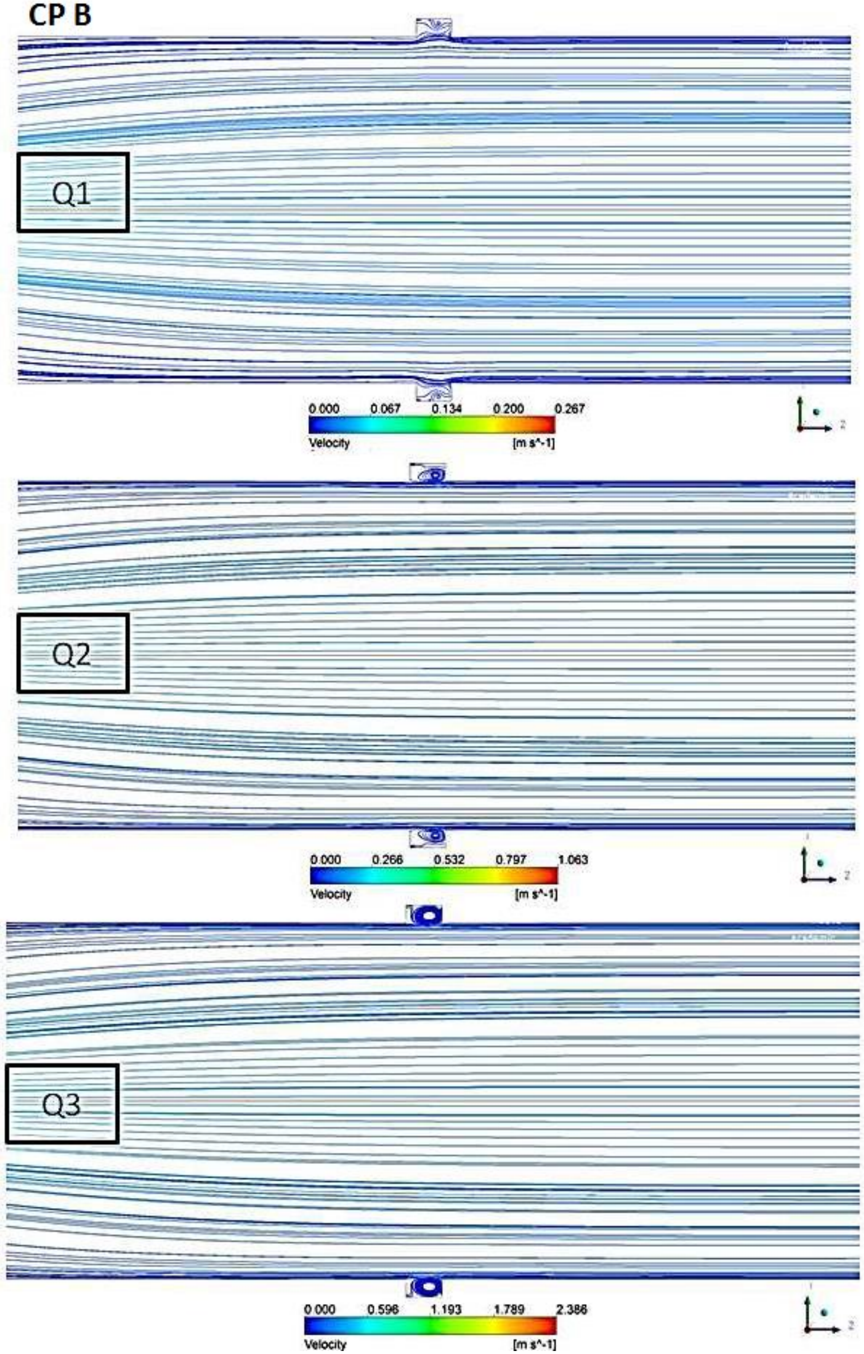
Velocities along the centre of the tubes

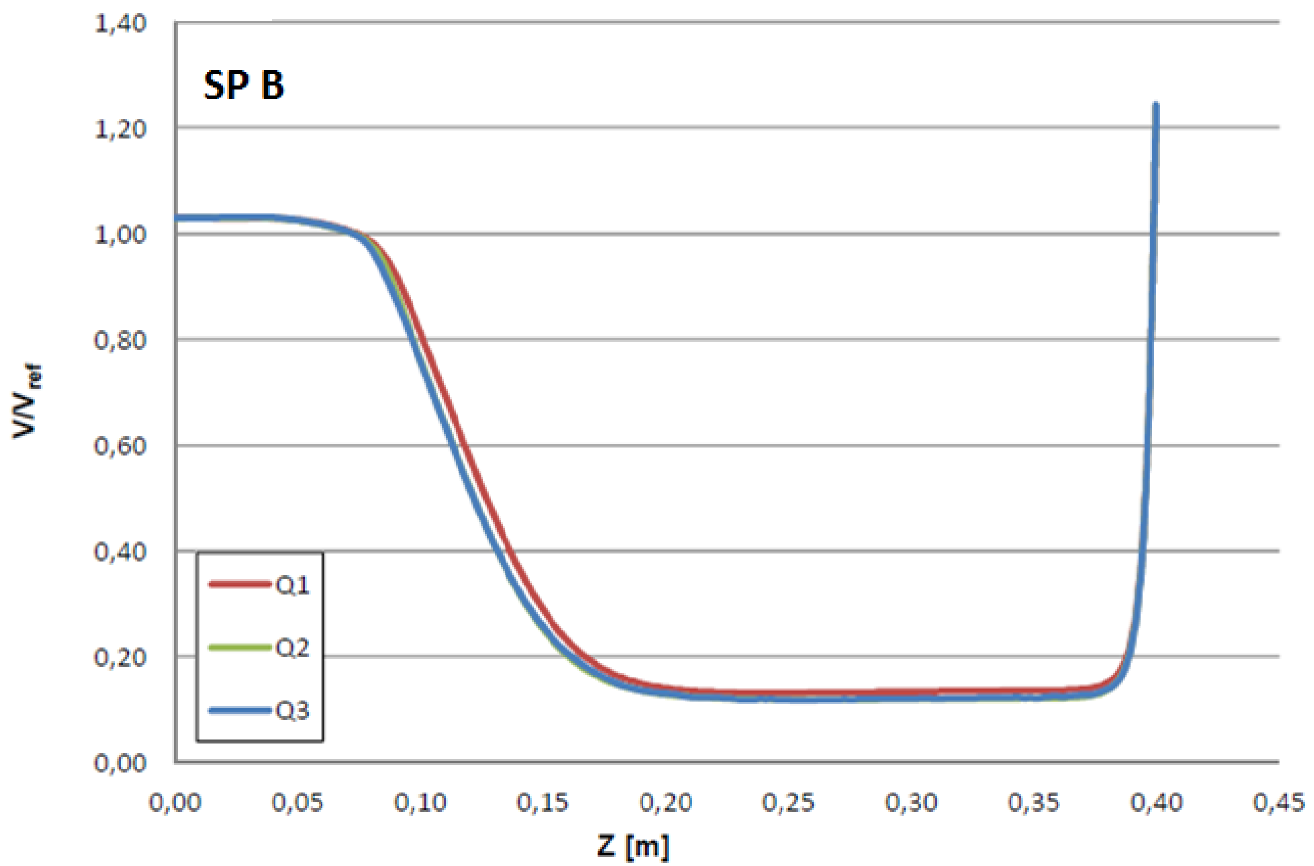
- Recirculation causes acceleration near the entrance and subsequent deceleration.
- The effect is stronger at higher flowrates.



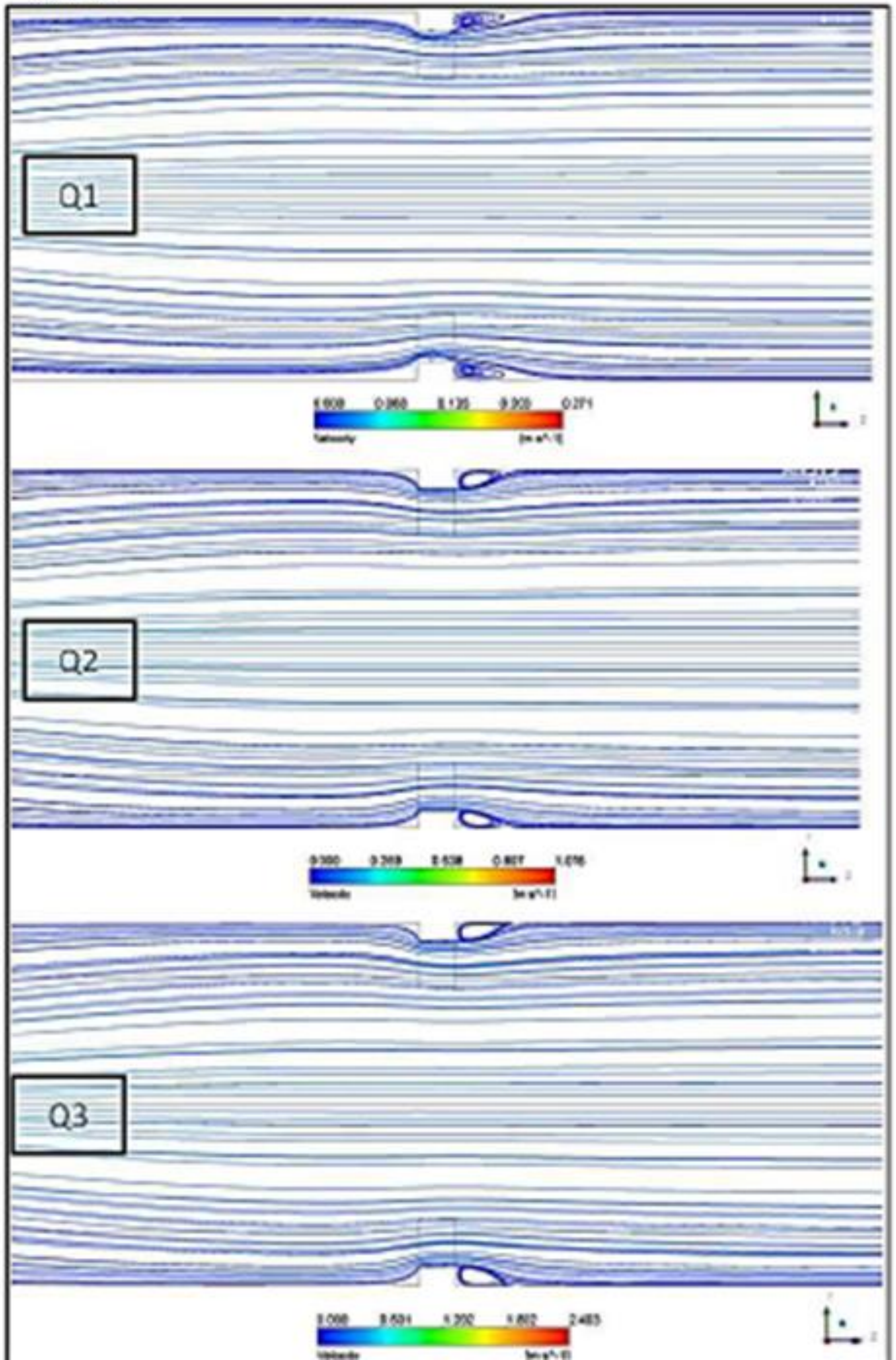


CP B


Q1
0.000 0.067 0.134 0.200 0.267
Velocity [m s^-1]
Q2
0.000 0.266 0.532 0.797 1.063
Velocity [m s^-1]
Q3
0.000 0.596 1.193 1.789 2.386
Velocity [m s^-1]


SP B
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
V/V_ref
0,00
0,05
0,10
0,15
0,20
0,25
0,30
0,35
0,40
0,45
Z [m]
Q1
Q2
Q3

SP C



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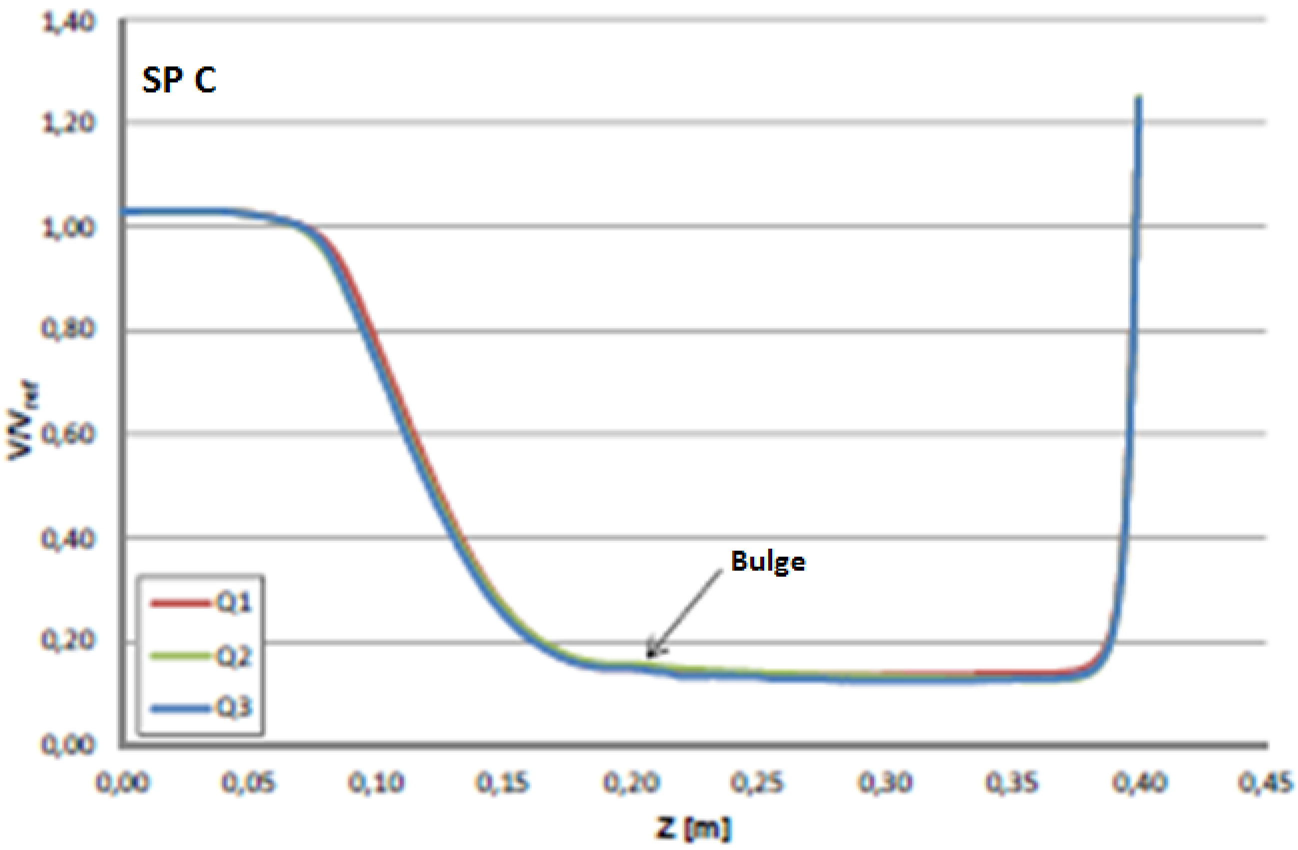

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Conclusions

- Dye tracers are not as effective as radiotracers due to the need of sampling and the lesser frequency of measurements.
- Qualitative differences could be noticed in the tracer response patterns of normal and damaged pipes.
- Scaling was more sensitive to the reduction in the time of transit

Conclusions

- Recirculation at the entrance increases with flowrate.
- Changes in the patterns of the RTD curve were due to discontinuities in the internal surface.
- Tracer dispersion consistently increased as flowrate increases, and the effect is more sensitive for scaling than for pit corrosion.

Conclusions

- Tracers, especially radiotracers, have a potential to detect damages that can introduce a discontinuity in the inner surface of pipes, namely pit corrosion and scaling.

THANK YOU FOR YOUR ATTENTION!

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