Shot-to-Shot Engineering

Hot Flow Test Bench for Aftertreatment Systems (ATS) Testing - Features and SCR Analysis Capabilities

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Shot To Shot Engineering S.r.l. – Via Val di Rocco, 38/c 06134 Perugia (Italy) – Phone: +39 0753747523 – Mail: info@stse.eu

❖ *The STSe Hot Flow Test Bench (HFB) main features*

- Max air flow rate 800 kg/h @ 600 °C(*) max temperature, with regenerative configuration to reduce the input power.
- Electric heaters (70 kW) to obtain high test reproducibility, fully controlling the gas stream composition.
- Controlled pollutant flows from tank (*e.g.* NO and NO_2 to test SCR systems) to obtain accurate and flexible gas composition.
- Fully programmable UWS injection strategy with continuous UWS flow rate monitoring.
- Flexible test section design to install complete exhaust line layout.
- AVL FTIR Sesam i60 - 5Hz; Diesel, Natural Gas and Gasoline packages - integrated with proprietary HFB control software.

❖ *Available diagnostics*

a) Aftertreatment system overall characterization (NO_x conversion efficiency, ammonia slip, ammonia storage, UWS dosing limit maps) by AVL Sesam i60 FTIR gas analyzer.

b) Evaluation of production NO_x/NH_3 sensors accuracy and sensitivity to insertion position.

c) Chemical species distribution and flow velocity local maps on catalyst outlet face, obtained by a non-intrusive proprietary Local Gas Sampler (LGS) integrated with the FTIR gas analyzer.

d) Internal UWS deposits evaluation by SCR converter high-temperature weighing and endoscopic analysis.

e) ATS internal/external surface temperature characterization and analysis by high sensitivity thermography.

f) High temperature UWS spray analysis (jet evolution and sizing) in quiescent conditions.

g) UWS spray – ATS layout interaction analysis in realistic flow and temperature by imaging inside the ATS.

(*) at the heating section exit; the actual temperature at the test section is design dependent

a) – b): ATS overall characterization (Conversion Efficiency) & production NO_x /NH_3 sensors response

Conversion Efficiency Test main phases:

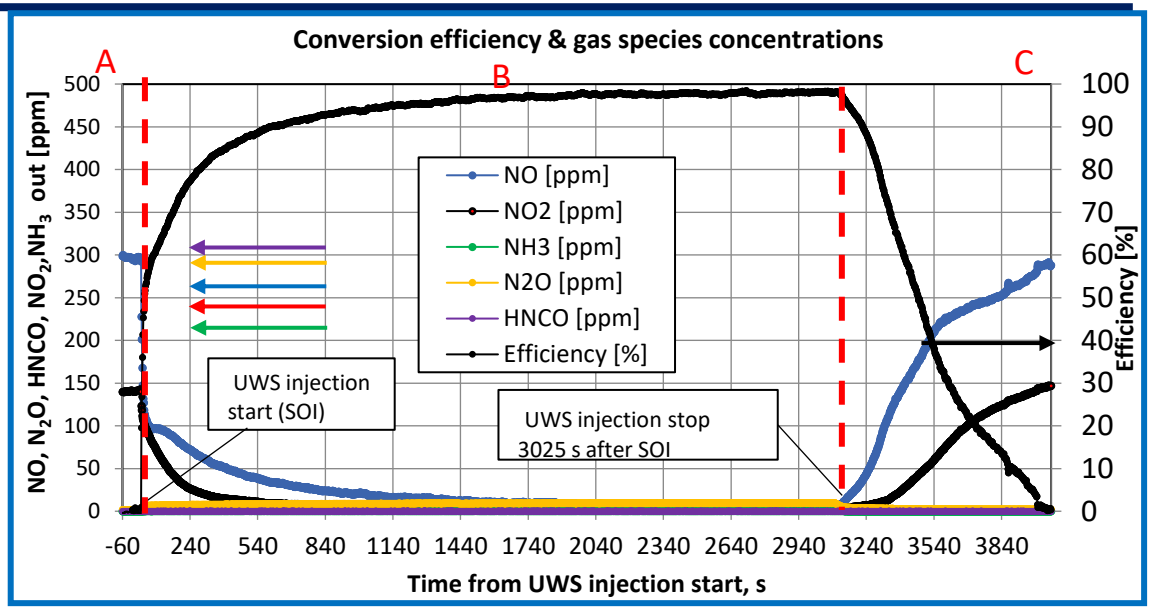
Phase A: Reference test conditions build-up. NO_x-only insertion (60 s).

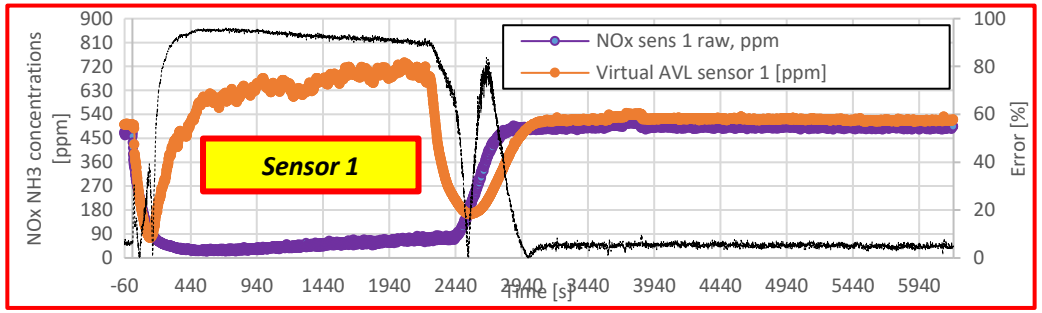
Phase B: Global efficiency. NO_x+UWS insertion.

Phase C: Ammonia Storage: NO_x-only insertion - Initial conditions check.

Hot Flow Bench can be equipped with production NO_x/NH_3 sensors, in order to evaluate their accuracy and the influence of their position along the ATS layout, using the AVL FTIR gas analyzer as a reference. Sensors can be installed in any position. In this slide an example of 3 sensors installed at three different positions is shown:

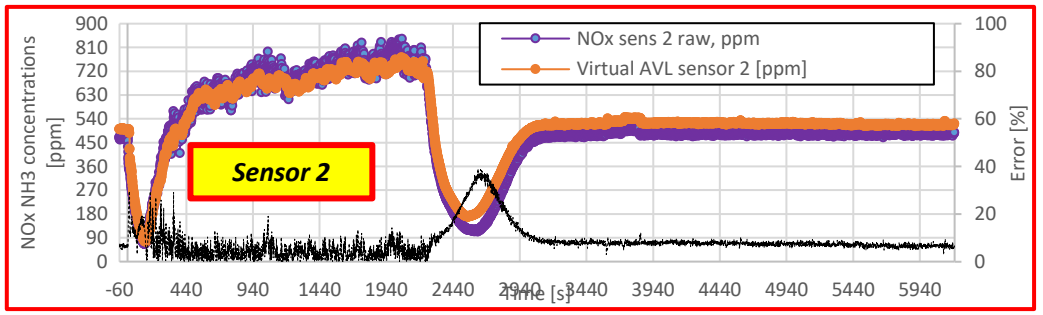
- Sensor 1: close to the converter exiting cap
- Sensor 2: in the middle between Sensor 1 and Sensor 3
- Sensor 3: at the same position of FTIR collecting probe

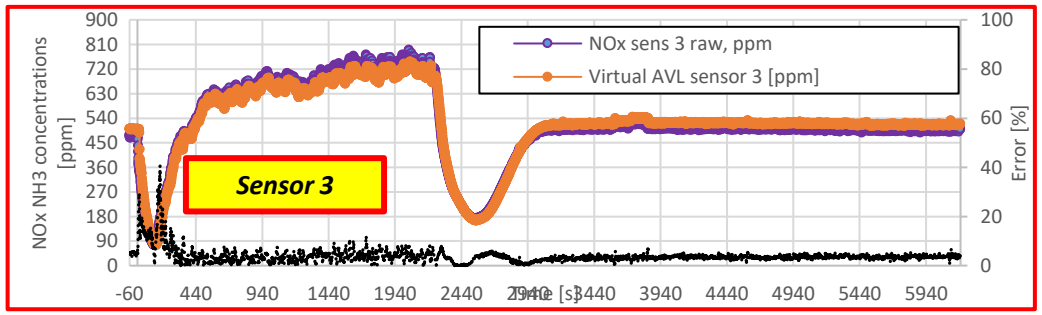




TEST CONDITIONS e.g:

Mass Flow Rate=250 kg/h
T DOC OUTLET=225°C
NO_x concentration= 500 ppm
NH_3/NO_x alpha ratio *α=3*

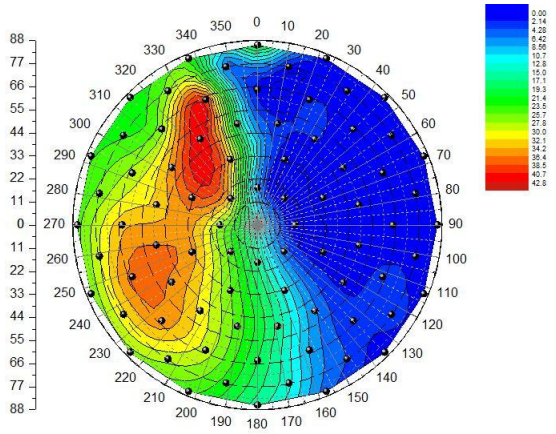




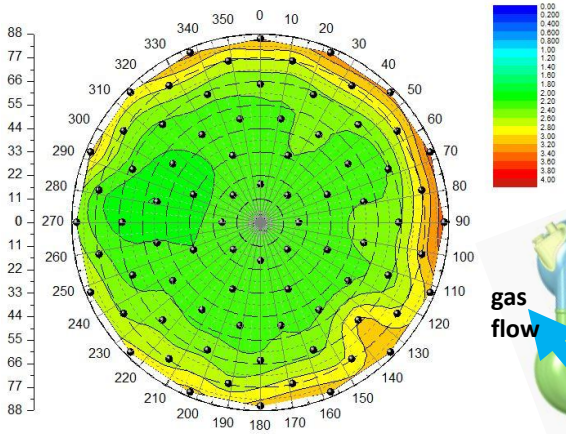
TEST CONDITIONS e.g:

Mass Flow Rate=364 kg/h
T DOC OUTLET=235°C
NO_x concentration= 437 ppm
NH_3/NO_x alpha ratio *α=1.1*

c) – d): Maps of species concentration & Flow velocities – Uniformity Index - Urea Deposits Evaluation

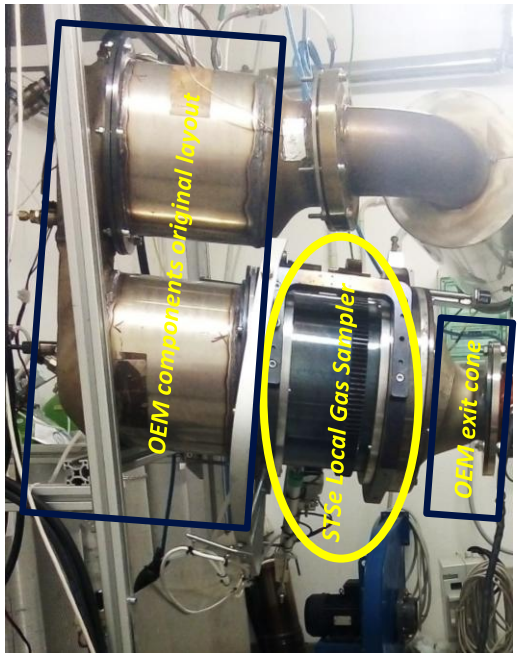


NO_x concentration map, SCR catalyst outlet section, ppm



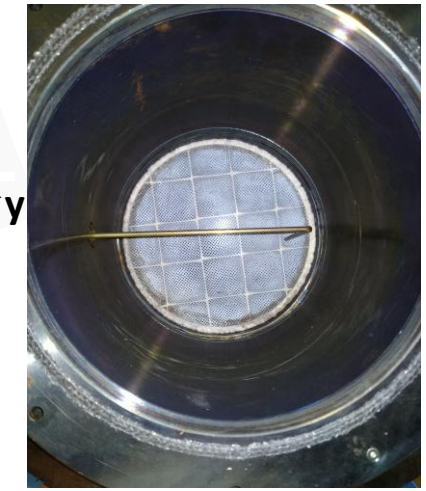
Velocities distribution map, SCR catalyst outlet section, m/s

TEST CONDITIONS e.g.:
Mass Flow Rate=126 kg/h
T DOC OUTLET=225°C
NO_x inlet concentration= 100 ppm

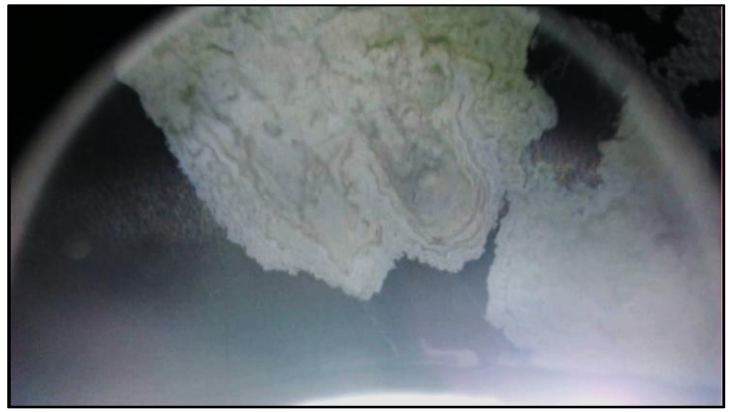


With the insertion of ***STSe Local Gas Sampler (LGS)*** at the SCR catalyst outlet it is possible to measure local gas concentrations and flow velocities, maintaining the original de-NO_x converter layout. The LGS is based on a Pitot-shaped collecting probe moved by a 2-coordinate positioning system over a planar map composed of an arbitrary matrix of measuring points (typically, 50 to 150).
More than 25 species can be simultaneously acquired including: NH_3, NO, NO_2, N_2O, HNCO, H_2O, CO, CO_2, CH_4 and HC using the AVL Sesam i60 FTIR gas analyzer. When connected to a differential pressure sensor, the LGS enables velocity maps measurement. Temperature maps are also available by a built-in Tc.

Urea deposits evaluation is made both measuring deposits mass by weighing the complete de-NOx converter at the end of the test. Weighing is carried out by a precision balance (resolution 0,1 g) at controlled high temperature (180 °C) to improve accuracy. Deposits inside the converter are imaged by a 2-camera, high resolution endoscope.



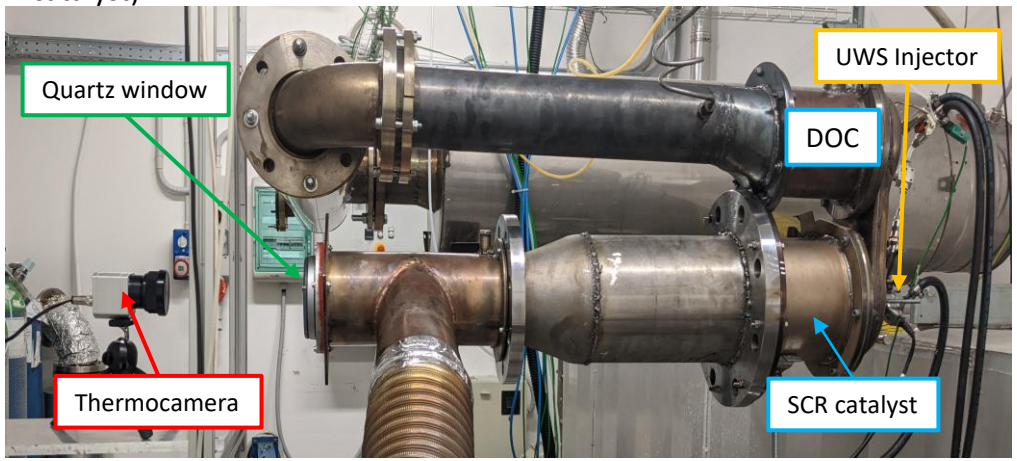
STSe Local Gas Sampler: *main features are the Pitot-shaped gas sampling probe and low-intrusiveness due to the external positioning mechanism.*



Urea deposit internal endoscope pictures sample

e) - Exhaust line internal/external thermography in realistic operating conditions on STSe HFB

An example of **SCR catalyst outlet surface thermographic analysis** is showed. A de-NOx automotive complete system is tested on the STSe HFB, with slight modifications on its outlet section layout. The modifications are required to allow the thermographic internal acquisition maintaining the de-NOx system in realistic operating conditions (UWS injection and prescribed backpressure level post-SCR catalyst).

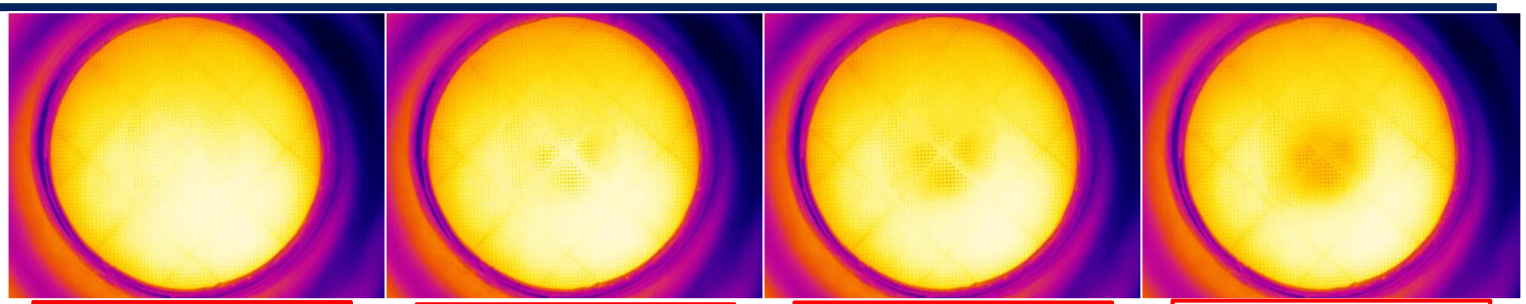


During the acquisition UWS is injected in the mixer section. It is clearly visible from the images the effect of UWS injection on the temperature distribution over the SCR catalyst outlet surface.

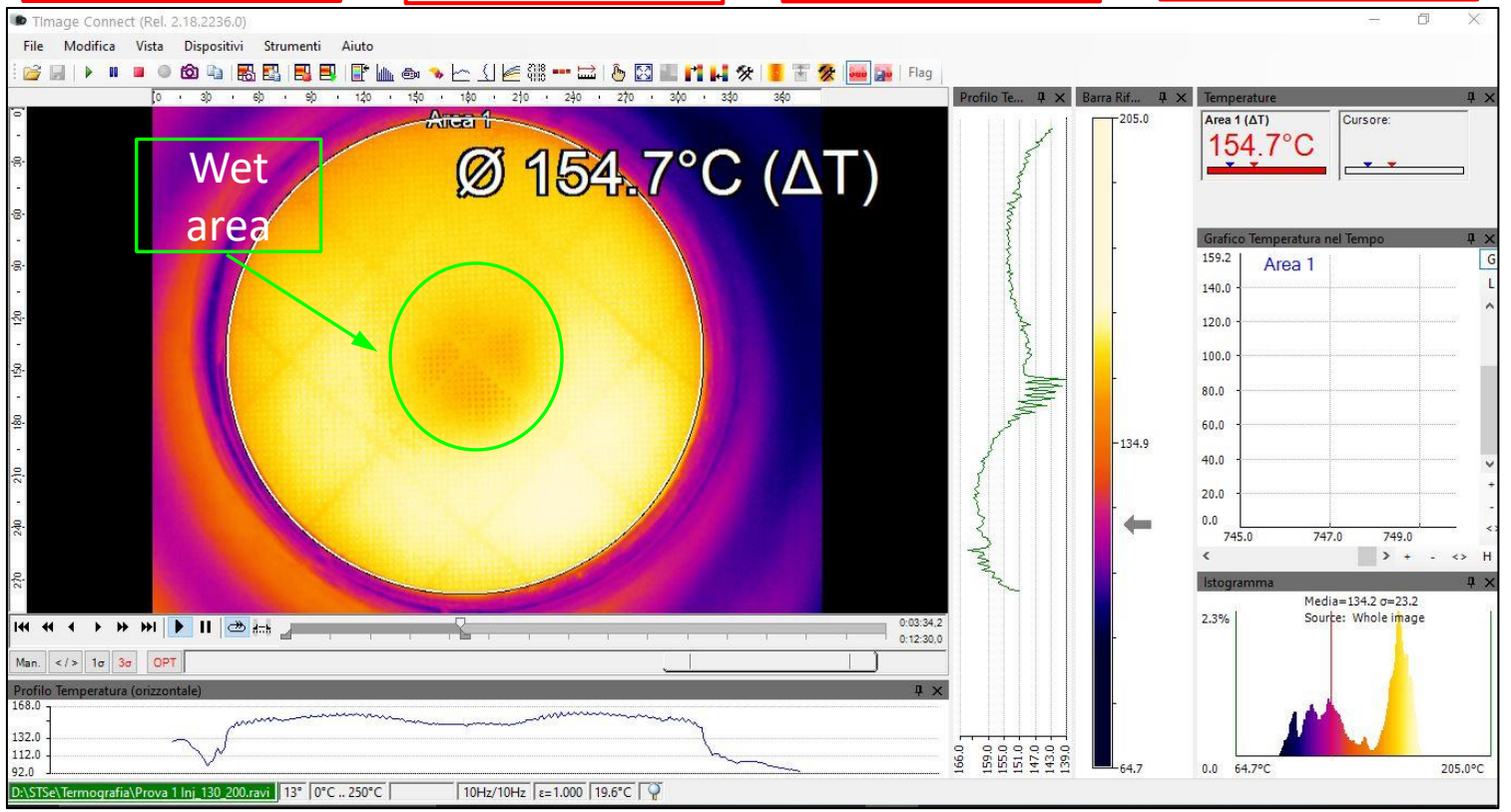
This kind of analysis can be easily applied also on the converter external surfaces and on the other internal components, e.g. mixer surfaces (with dedicated optical access and slight layout modifications)

Temperature can be measured along arbitrary area/lines or single image pixels.

TEST CONDITIONS, e.g.:
Mass Flow Rate=130 kg/h
T DOC OUTLET=200°C
T SCR outlet- 160°C

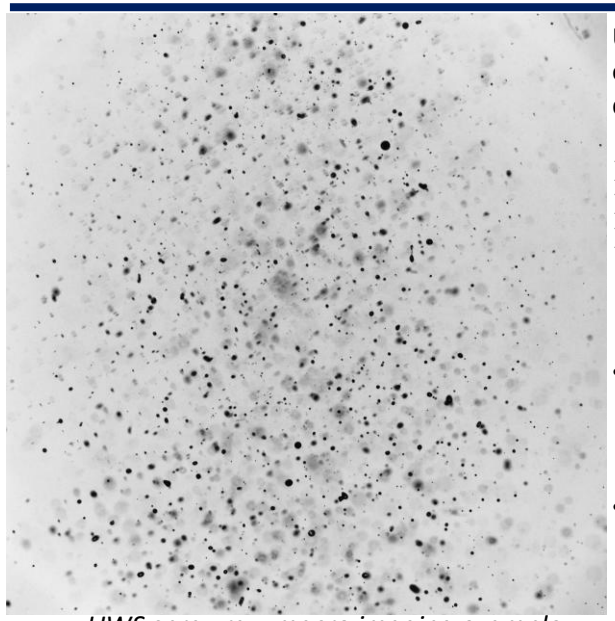


Start of Injection (SOI) | 15 s after SOI | 30 s after SOI | 45 s after SOI



Thermographic internal video (SCR catalyst outlet surface). Temperature field time-history from UWS injection start @ standard 4Hz injection frequency. Real time axis.

f) - High temperature UWS spray analysis (jet evolution and sizing) in quiescent conditions



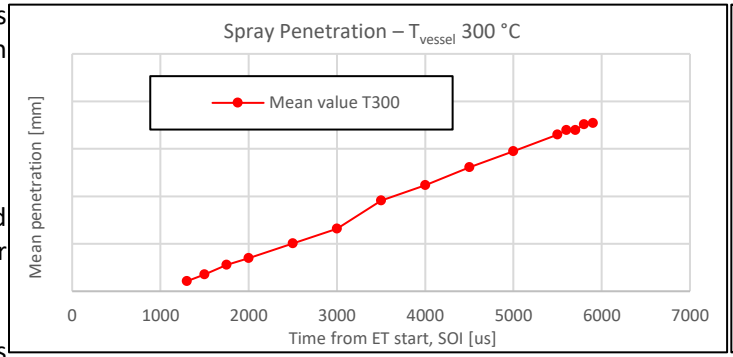
UWS spray raw macro imaging example

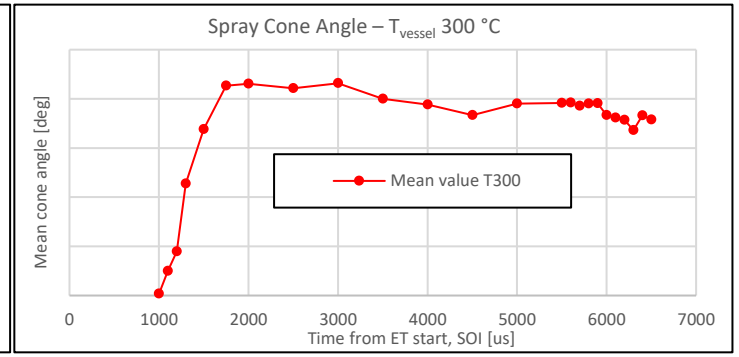
UWS/other fluid spray analysis in terms of global evolution and droplets sizing in quiescent conditions:

- Vessel temperature up to 600°C
- Vessel pressure up to 5 bar,a
- Controlled temperatures of injected fluid, injector body and tip, injector coolant.

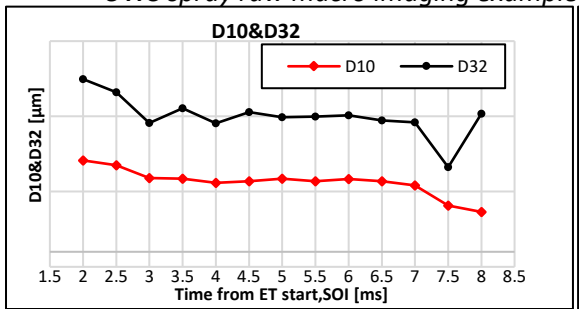
- Global spray characterization analysis following SAEJ2715 using fast shutter or high speed imaging.

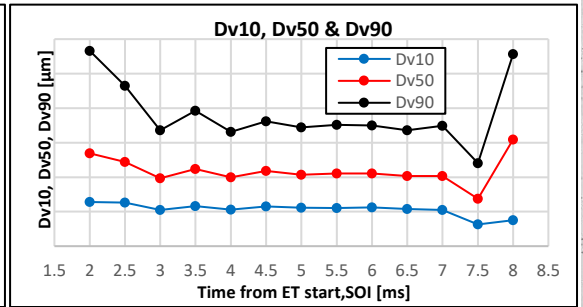
- Droplets sizing analysis by macro imaging acquisition (spatial resolution down to 3.5 µm/pixel) and proprietary postprocessing procedure.

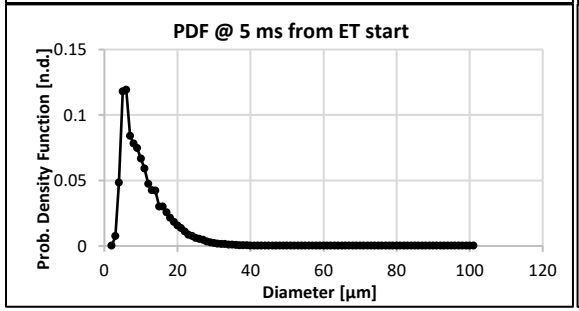


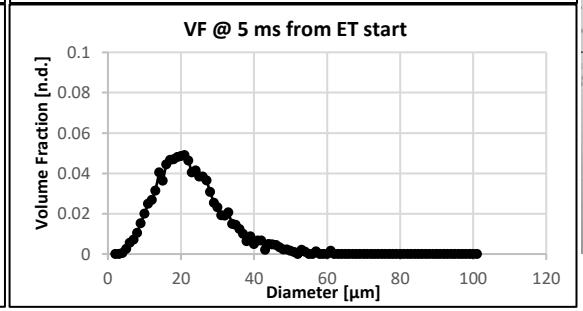


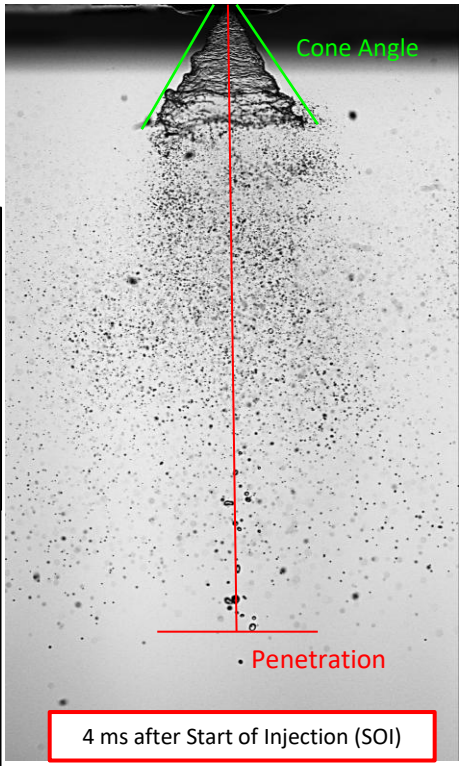
Spray penetration and cone angle curves example

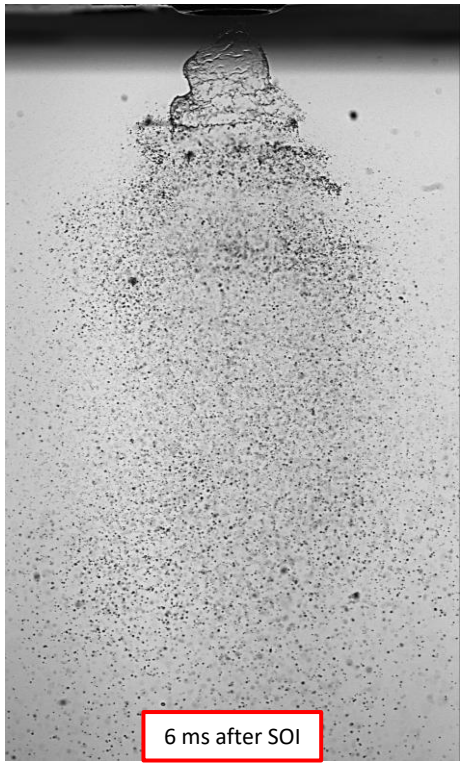










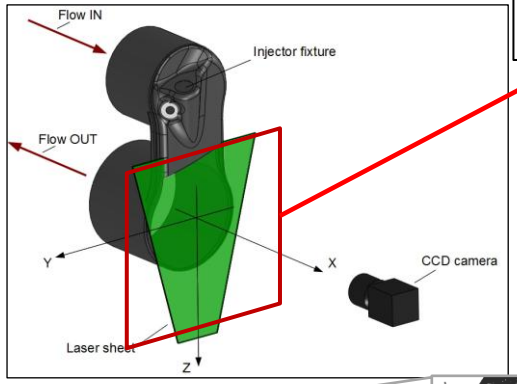


UWS global jet evolution raw imaging examples

g) - Internal converter UWS spray imaging (spray targeting) in realistic operating conditions

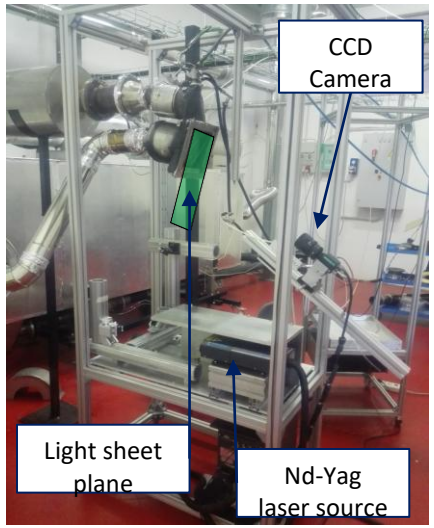
LSI set-up

- The laser beam is treated to obtain a light sheet. The laser sheet coincides with the YZ plane, parallel to the SCRF inlet section;
- The CCD camera optical axis coincides with SCRoF main axis.

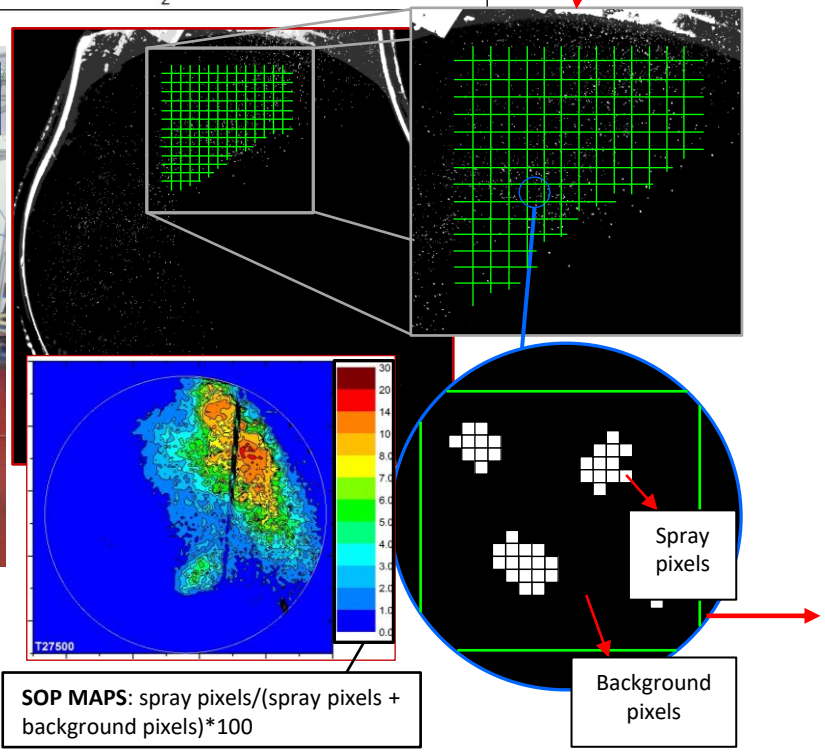


Internal spray raw pictures acquired on HFB

Proprietary Postprocessing

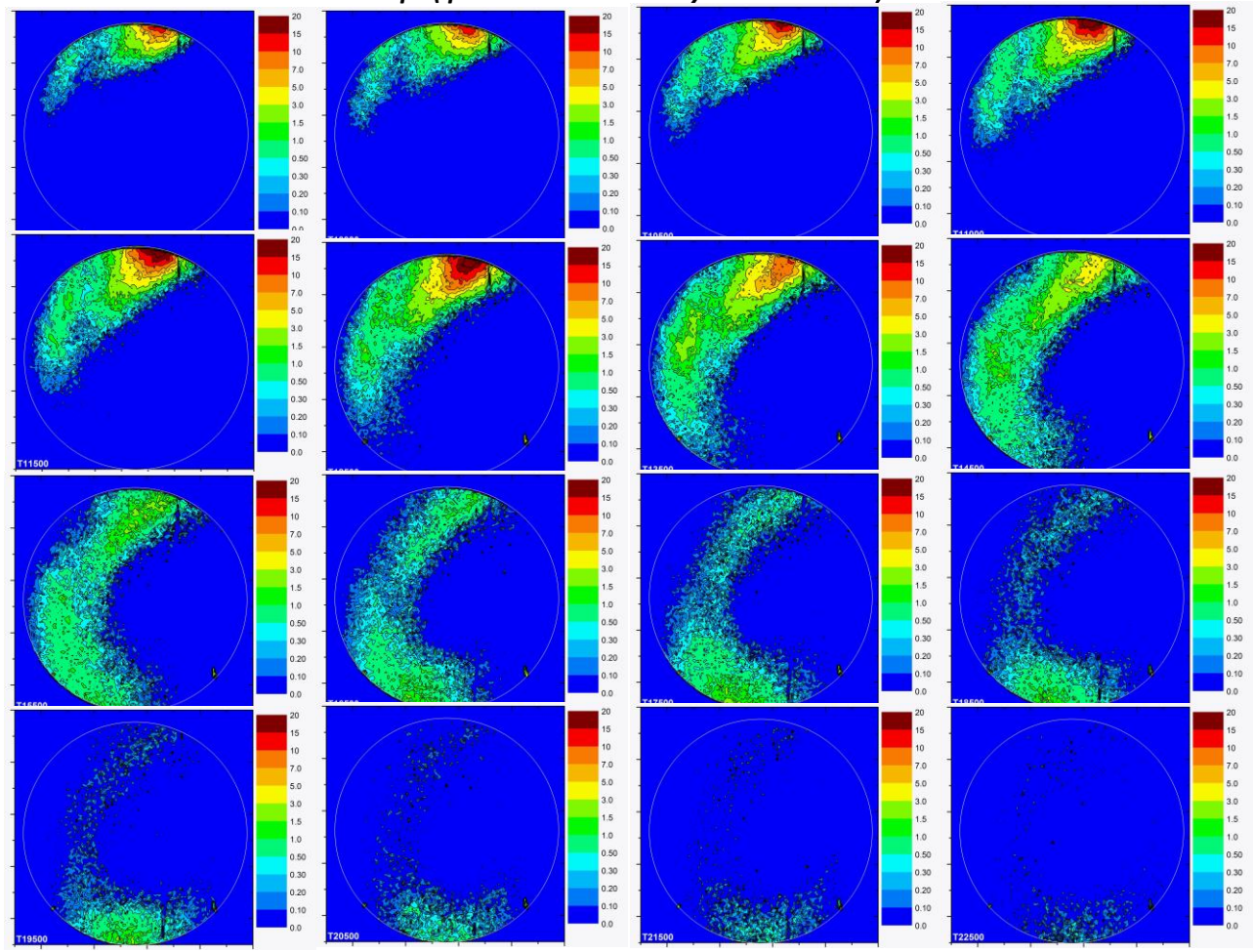


Aftertreatment system on STSe HFB



SOP MAPS: spray pixels/(spray pixels + background pixels)*100

SOP maps (post mixer SCR catalyst inlet section)



- The resulting matrix is representative of the drops occurrence frequency in each image subset. The computed matrix is therefore a useful mean to perceive the spray spatial distribution at SCRF inlet section, at the examined timing and event.
- The obtained matrixes are then represented as false color maps, which can be interpreted as liquid phase occurrence or occupancy probability maps over the examined plane.

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Thank you for your attention!

the STSe Team