Parametric tests to study the potential of the Absorber Continuous Emissions Measurement System (ACEMS) prototype

PCCC7-Conference

26/Sept-2023, Pittsburgh

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Outline

- Background
- Objectives
- ACEMS parametric testing
- Results
- Conclusions

Objectives

- Acems Improvements on current prototype
  - increase sampling frequency
  - equip ACEMS with automated gas sampling capability
  - expand ACEMS trace analytes list
- testing of the the improved ACEMS Protype

ACEMS - Background

- The Concept derived from an existing SINTEF PATENT (No. PCT/EP2011/073557), **Publication Number WO/2012/085061**

- The main concept is based on a fast-loop (fluid transfer) which transfers a liquid sample from a liquid source (series of impingers) to a remote liquid sample analyser by use of timers. The system comprises of a capillary that connects the liquid source and the liquid analyser. Successfully demonstrated in a project but is rather *complex*.

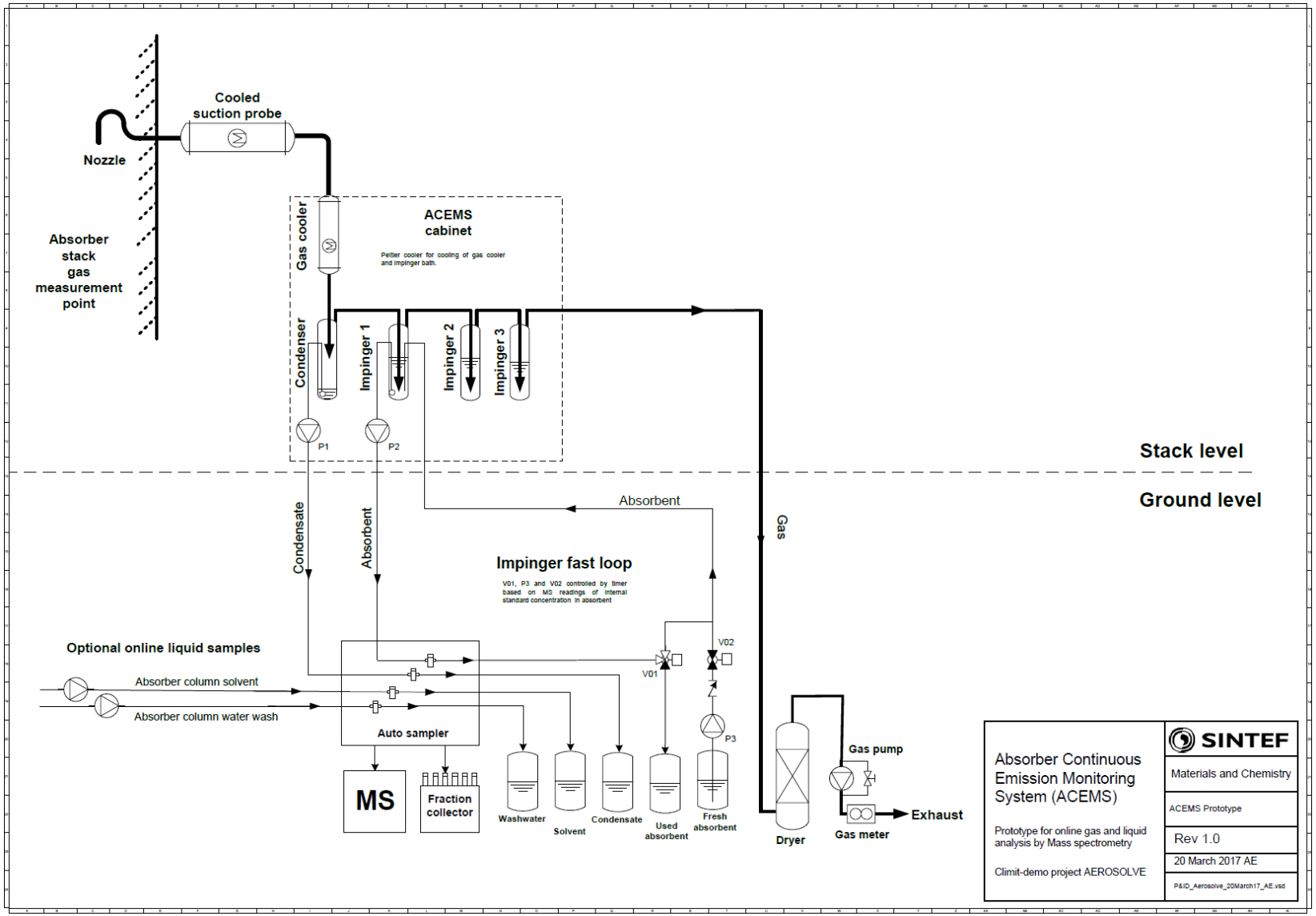
- A simplified version was developed (2018 – 2019 in the ACT ALIGN–CCUS). The prototype of the design, was built and successfully demonstrated for emission monitoring at Tiller.

- Demonstration of a novel instrument for online monitoring of absorber emissions to air

  Aslak Einbu et al: *https://www.sciencedirect.com/science/article/pii/S1750583621001328?via%3Dihub*

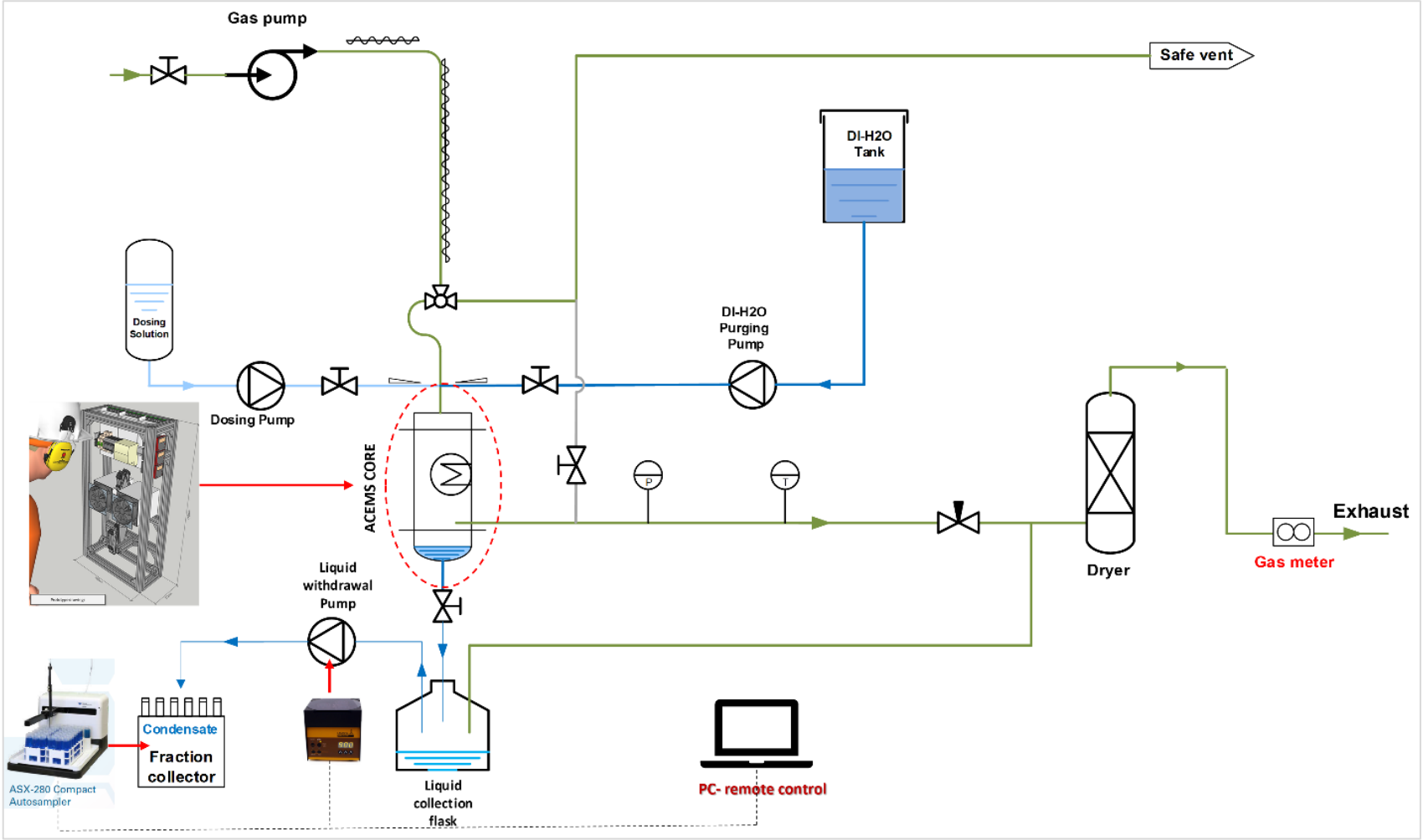
Original Prototype (Design)

- Though successfully demonstrated, the concept had appreciable complexity that compromised its robustness for 24/7 industrial applications.



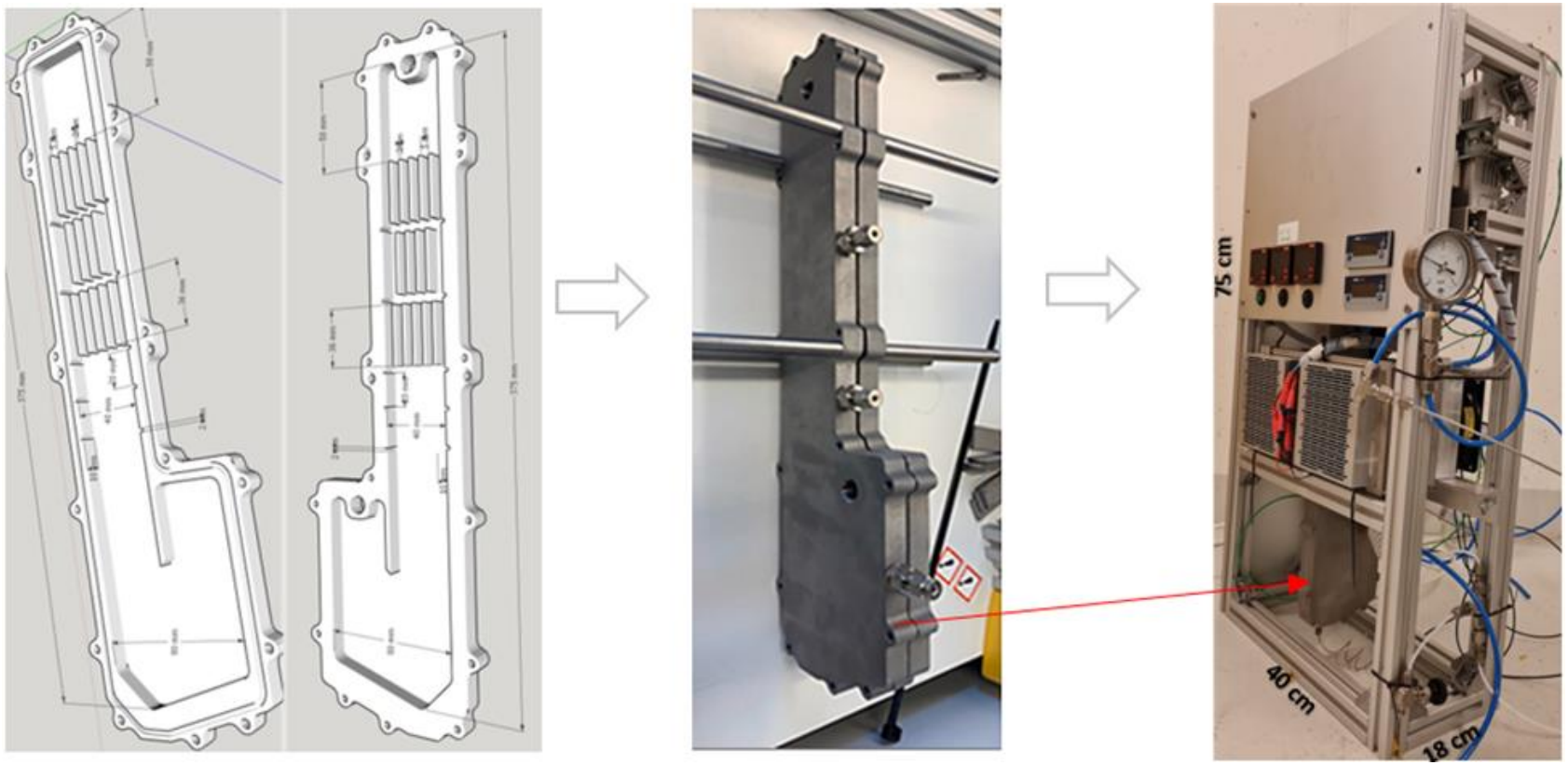
Current (Design) Protype

- The current version of the simplified design. The main component is a custom gas/mist cooler design, equipped with appropriately integrated Peltier cooling elements.
- As such, the gas cooler only requires electrical power as the only utility needed for operation of the unit.



Current (Design) Protype

a revised design version was proposed with significant reduction in complexity, involving a high efficiency single stage gas cooler tailored for maximum capture of absorber mist and with continuous collection and analysis of liquid condensate containing the captured analytes of interest



ACEMS tests prototype Demo.

https://www.sciencedirect.com/science/article/pii/S1750583621001328?via%3Dihub

(based on ACT ALIGN-CCUS)

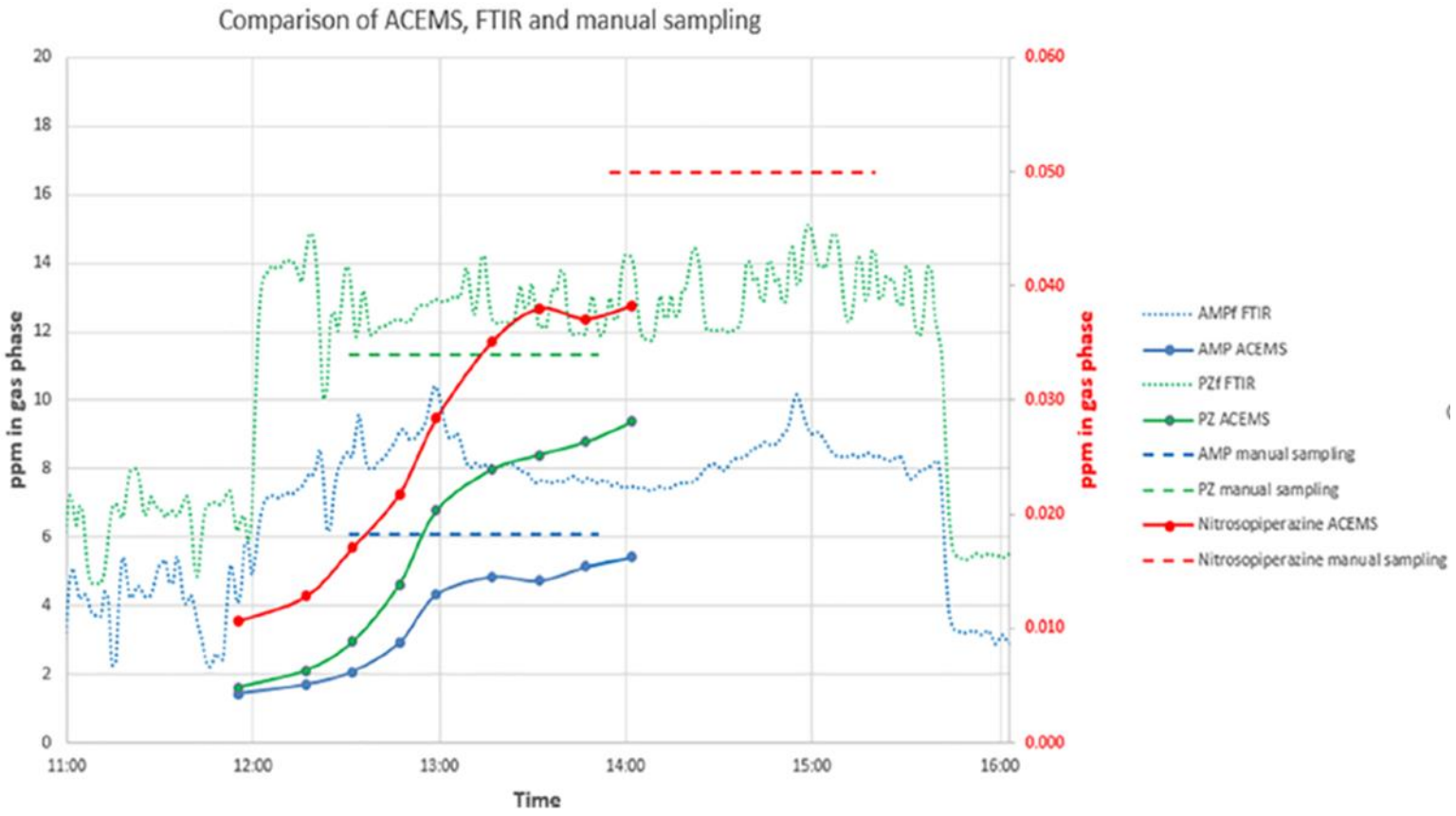
Demonstrated successful measurements

(vs. FTIR vs Manual Sampling)

1. Amines
   a. Piperazine
   b. AMP
2. Nitrosamines
   a. Nitroso-piperazine

Potential for expansion to include

1. Alkylamines
2. Nitramines
3. Degradation products

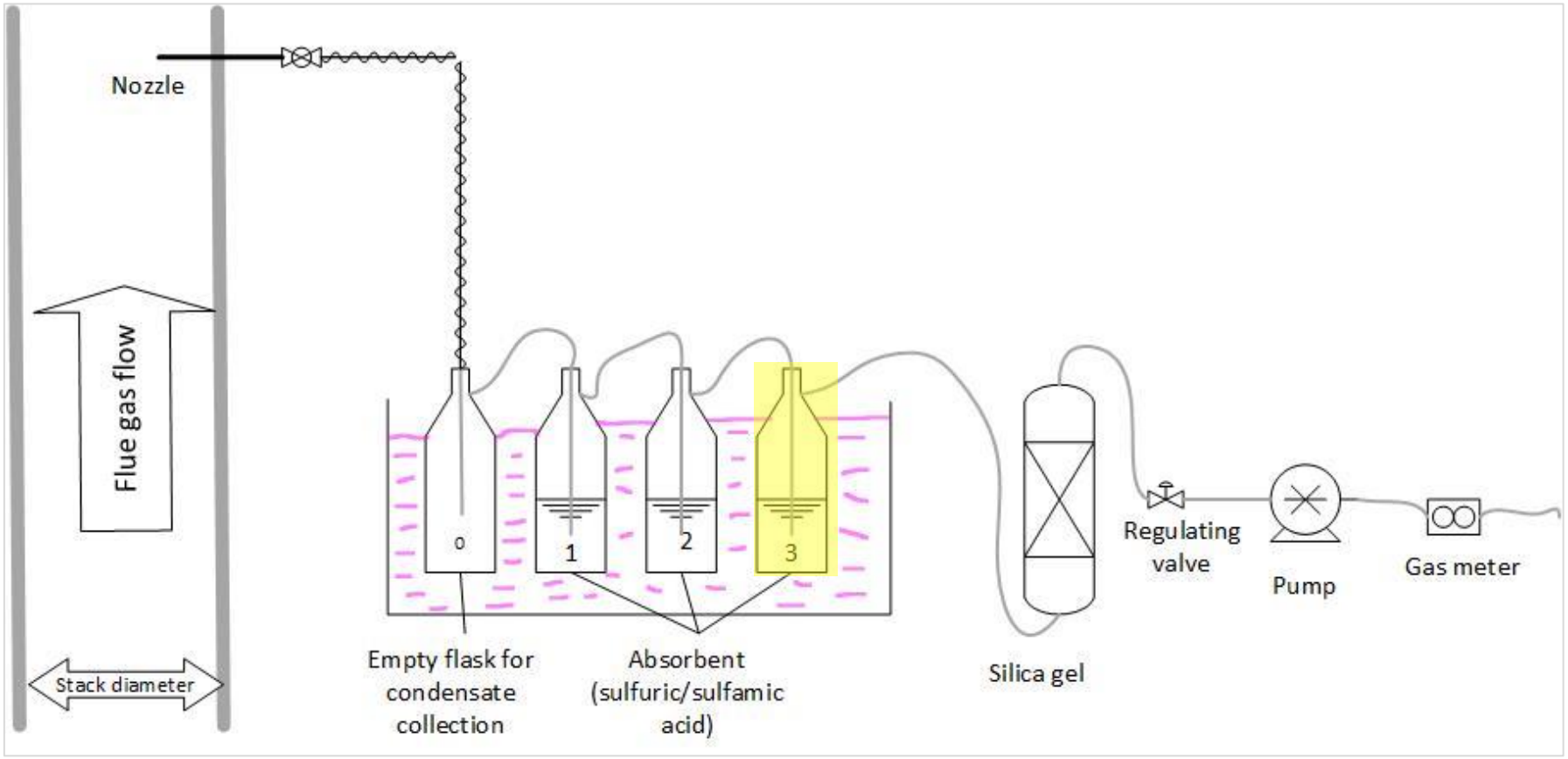


New Improvements (Scope Project – CESAR1 solvent)

- Improvement in some aspects
  - Increase sampling frequency
    - Capability to track dynamic situations/trends
  - Automation sampling
  - wider trace analytes list vs. previous demonstration
- An opportunity for parametric tests availed in the REALIZE project

Reference Method: Standard Impingers

The rule of thumb used for this type of sampling is that 90% (or more) of the captured component is to be found in the series preceding the last flask/bottle in the chain, ideally resulting in the last flask with no analyte found. This is considered as sufficient criteria for adequate capture efficiency for manual emissions sampling.



Reference Method: Standard Impingers

As a general comment: All performed measurements reveal good sampling efficiency for the analytes of interest i.e., Flask/bottle shows ≈ 0%, an indication that very little or nothing is escaping the impinger train (gives credibility to use this as the reference)

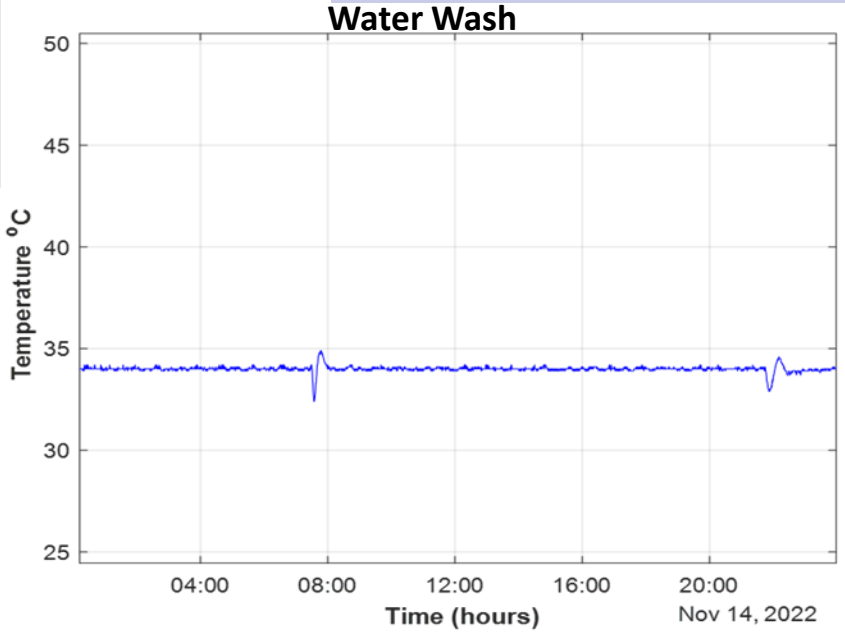
Process Conditions	Date	Compound	Percentage of the recovered analyte in the sampling flask [%]			
			Flask 0	Flask 1	Flask 2	Flask 3
Steady-state	19-Oct	Amine 1	99,07	0,86	0,07	0,01
		Amine 2	92,07	6,42	1,37	0,14
		Degrad. Product	97,46	2,44	0,11	0
		Nitrosamine	79,56	18,75	1,46	0,22
Steady-state	14-Nov	Amine 1	99,24	0,72	0,2	0
		Amine 2	96,17	2,88	0,57	0
		Degrad. Product	99,32	0,47	0,21	0
		Nitrosamine	94,25	5,36	0,39	0
Dynamic-state (increasing emissions)	16-Nov	Amine 1	99,29	0,6	0,08	0,03
		Amine 2	85,58	8,02	5,25	1,16
		Degrad. Product	99,26	0,57	0,12	0,05
		Nitrosamine	91,77	7,69	0,54	0
Dynamic-state (increasing emissions)	16-Nov	Amine 1	99,46	0,51	0,02	0,01
		Amine 2	99,2	0,57	0,13	0,02
		Degrad. Product	99,41	0,56	0,02	0,01
		Nitrosamine	97,26	2,5	0,24	0
Dynamic-state (increasing emissions)	16-Nov	Amine 1	98,97	0,98	0,04	0
		Amine 2	97,34	2,06	0,35	0,26
		Degrad. Product	98,58	1,39	0,03	0
		Nitrosamine	97,6	2,19	0,21	0
Dynamic-state (decreasing emissions)	17-Nov	Amine 1	99,68	0,26	0,04	0,02
		Amine 2	93,89	4,56	1,24	0,31
		Degrad. Product	99,63	0,17	0,2	0
		Nitrosamine	99,97	0,63	0	0
Dynamic-state (decreasing emissions)	17-Nov	Amine 1	97,39	2,05	0,47	0,09
		Amine 2	73,41	14,62	6,52	0,42
		Degrad. Product	97,66	1,79	0,43	0,13
		Nitrosamine	97,14	2,86	0	0

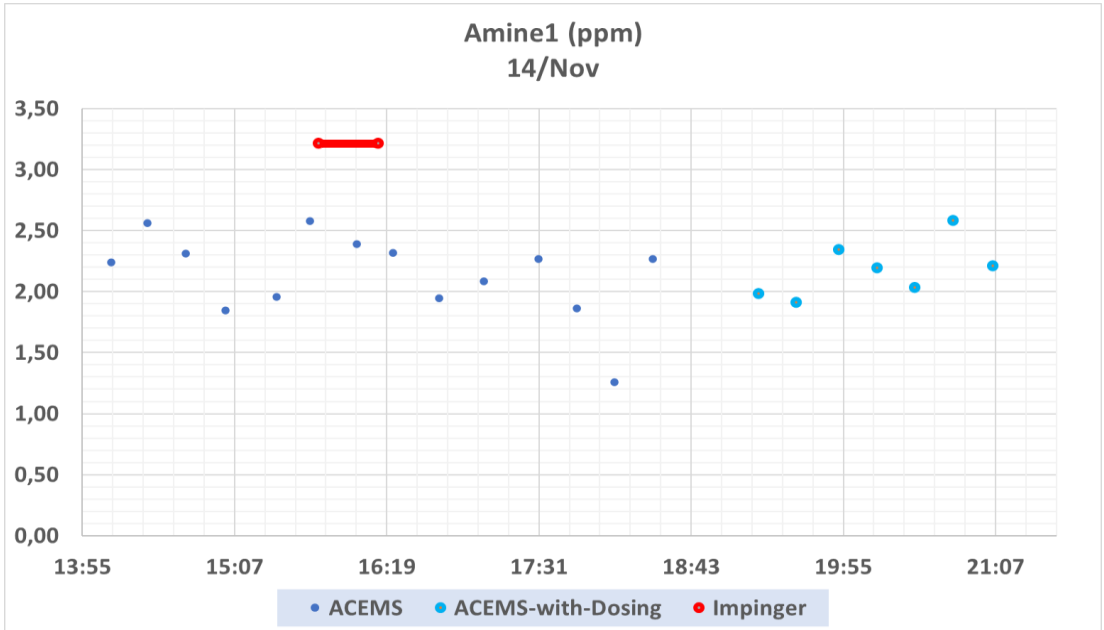
Process Conditions	Date	Compound	Percentage of the recovered analyte in the sampling flask [%]			
			Flask 0	Flask 1	Flask 2	Flask 3
Dynamic-state (decreasing emissions)	17-Nov	Amine 1	97,39	2,05	0,47	0,09
		Amine 2	73,41	14,62	6,52	0,42
		Degrad. Product	97,66	1,79	0,43	0,13
		Nitrosamine	97,14	2,86	0	0
Dynamic-state (decreasing emissions)	17-Nov	Amine 1	99,71	0,2	0,05	0,04
		Amine 2	96,57	3,43	0	0
		Degrad. Product	100	0	0	0
		Nitrosamine	98,77	1,23	0	0
Dynamic-state (increasing emissions)	1-Dec	Amine 1	99,18	0,78	0,03	0
		Amine 2	73,68	15,15	7,15	4,01
		Degrad. Product	99,67	0,33	0,01	0
		Nitrosamine	97,31	2,69	0	0
Dynamic-state (increasing emissions)	1-Dec	Amine 1	99,08	0,85	0,06	0
		Amine 2	80,05	14,39	4,5	0,2
		Degrad. Product	99,43	0,54	0,02	0
		Nitrosamine	97,09	2,91	0	0
Dynamic-state (increasing emissions)	1-Dec	Amine 1	97,34	2,54	0,11	0,01
		Amine 2	69,1	12,62	13,09	5,18
		Degrad. Product	99,76	0,11	0,07	0,06
		Nitrosamine	96,7	3,3	0	0
Dynamic-state (decreasing emissions)	2-Dec	Amine 1	97,8	1,98	0,12	0
		Amine 2	80,36	13,99	5,15	0,49
		Degrad. Product	96,55	3,12	0,23	0
		Nitrosamine	96,37	3,63	0	0
Dynamic-state (decreasing emissions)	2-Dec	Amine 1	96,5	3,27	0,22	0
		Amine 2	38,63	38,48	22,89	0
		Degrad. Product	98,19	1,75	0,06	0
		Nitrosamine	92,32	7,68	0	0
Dynamic-state (decreasing emissions)	2-Dec	Amine 1	97,14	2,11	0,12	0,03
		Amine 2	73,21	21,94	4,84	0
		Degrad. Product	99,1	0,86	0,04	0
		Nitrosamine	92,05	7,95	0	0

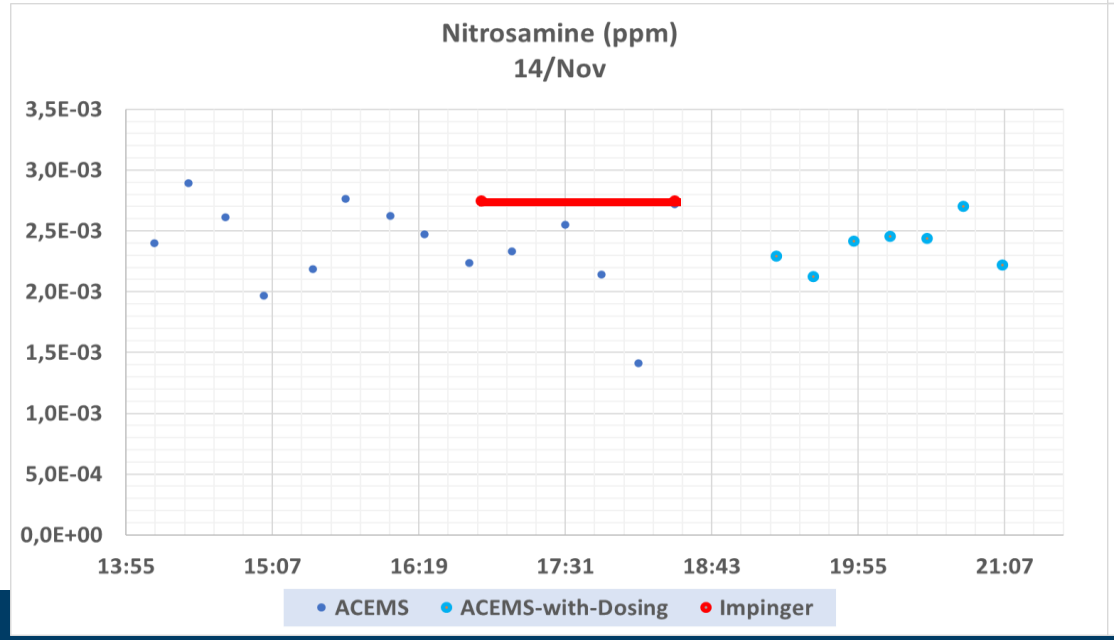
ACEMS test results

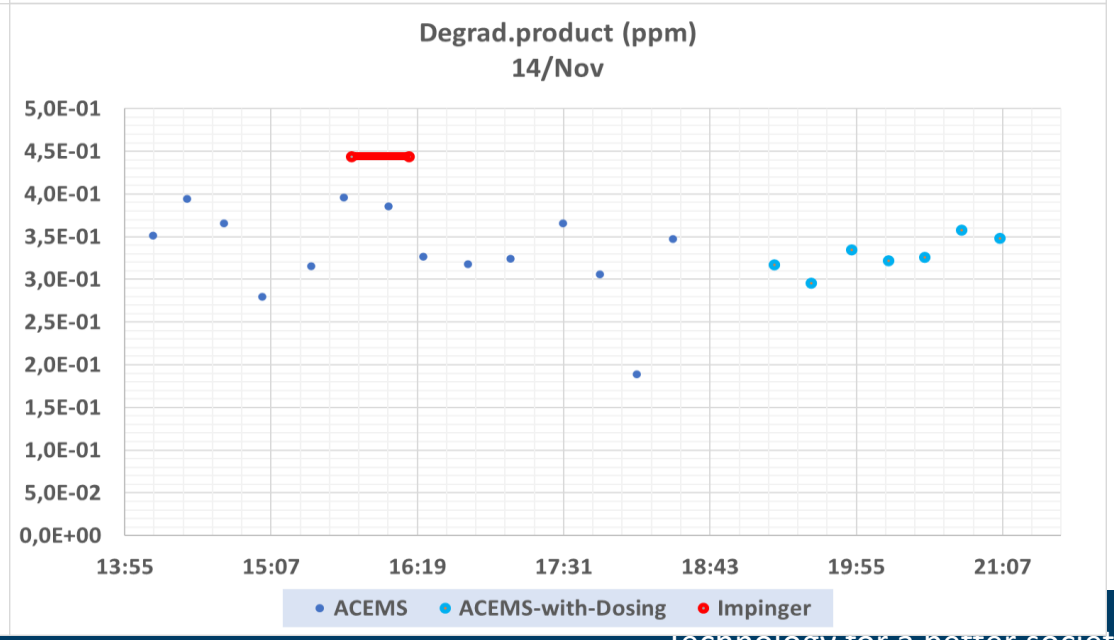
Criteria= Comparison of ACEMS results vs. corresponding impinger train reference (Capture efficiency ≈ 100%)

Steady State + dosing (14/Nov 2022)

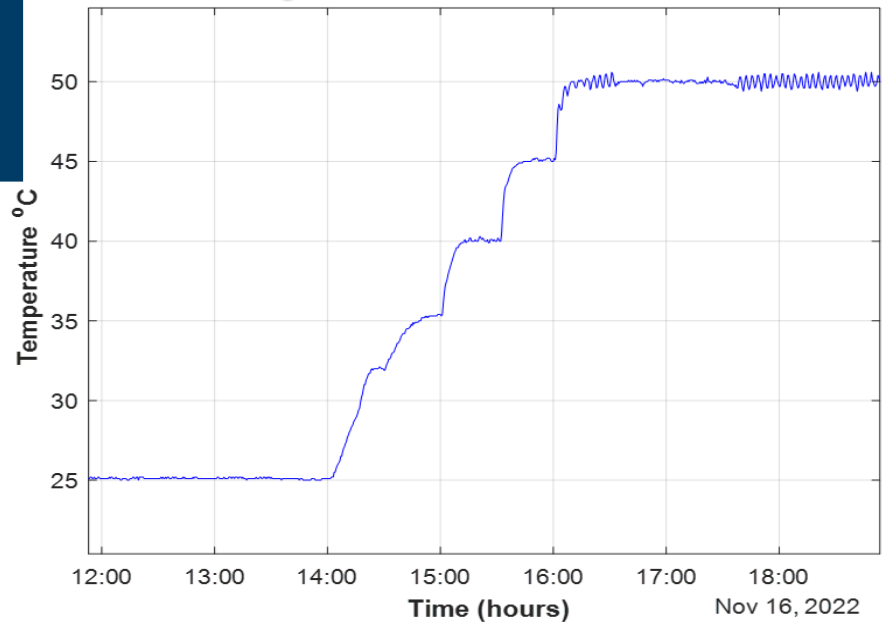


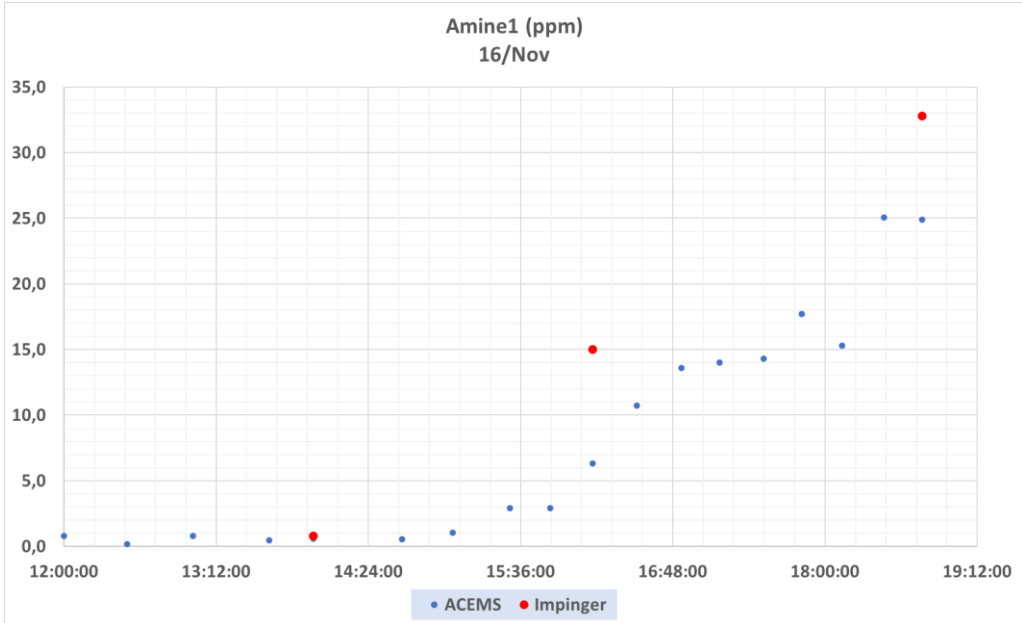


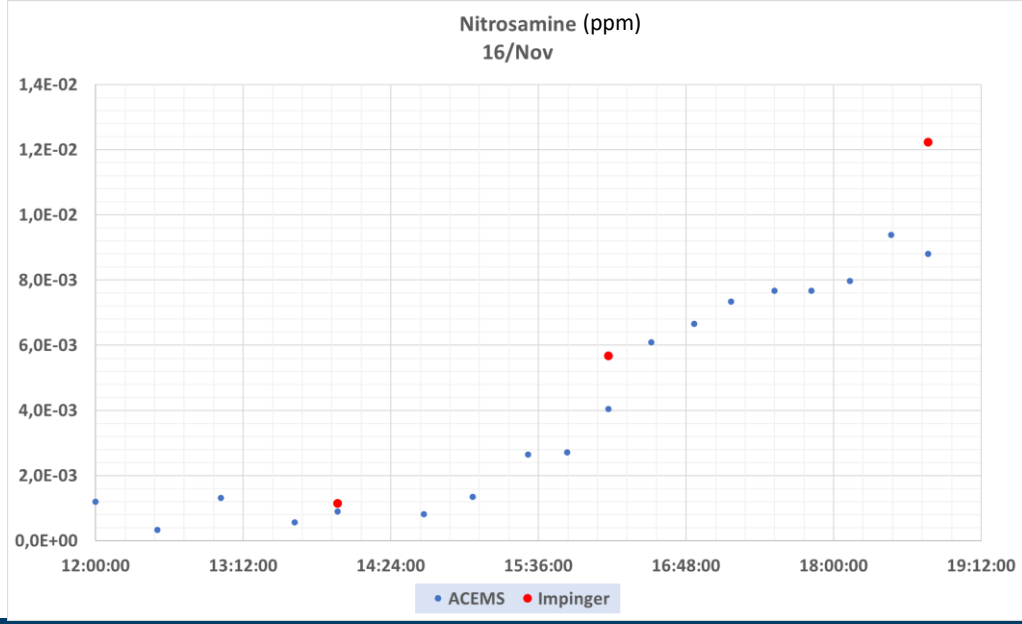


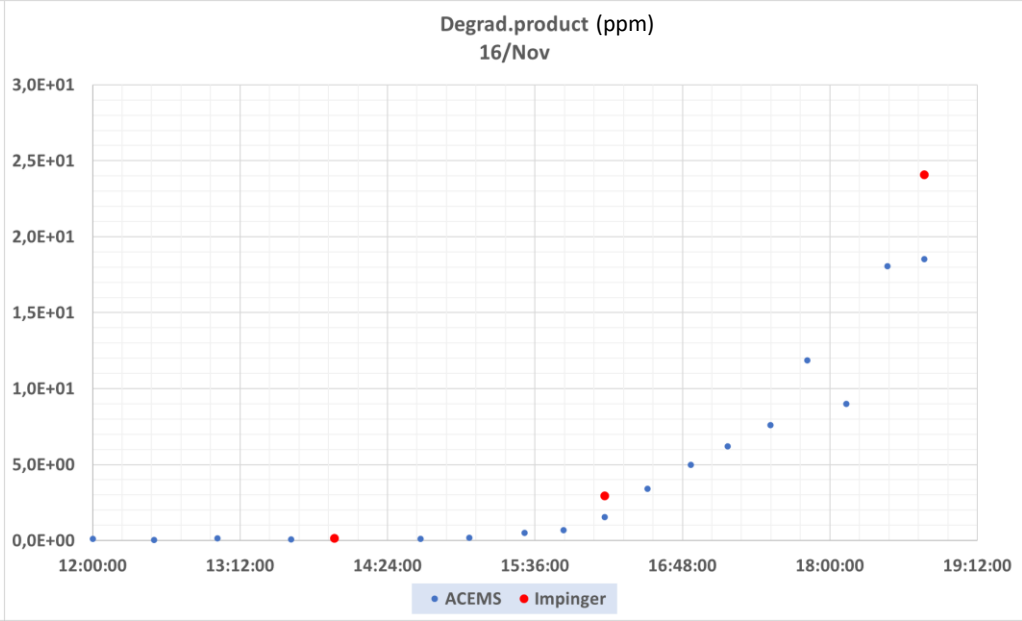


Dynamic state - increasing emissions (16/Nov-2022)

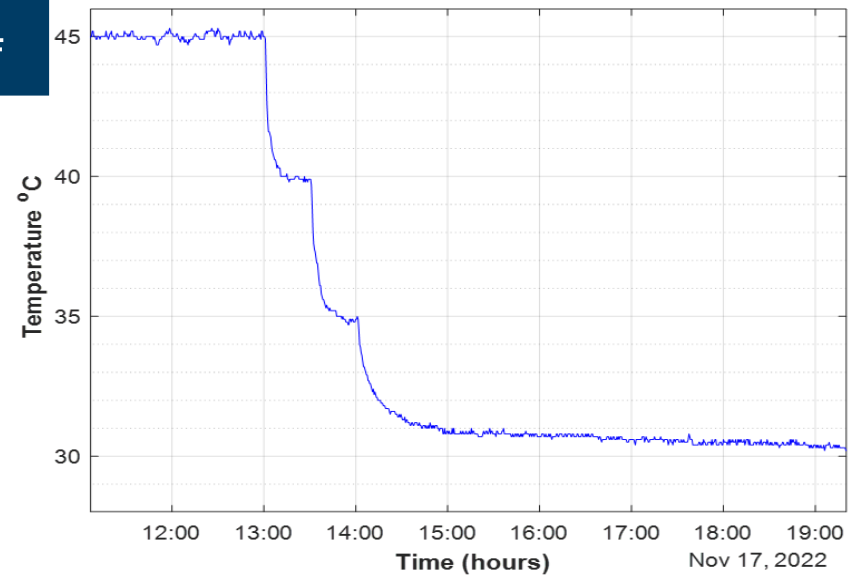


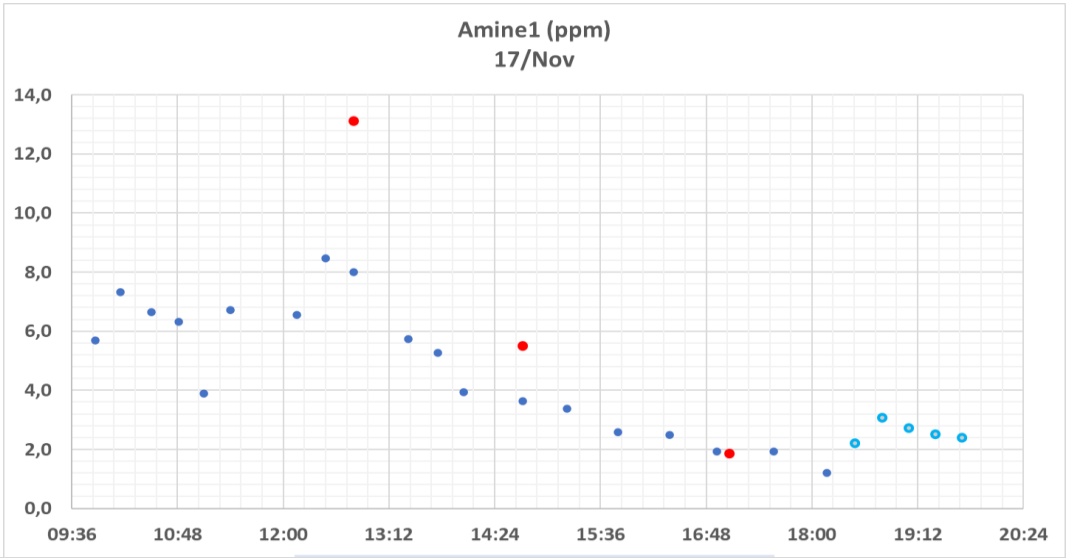


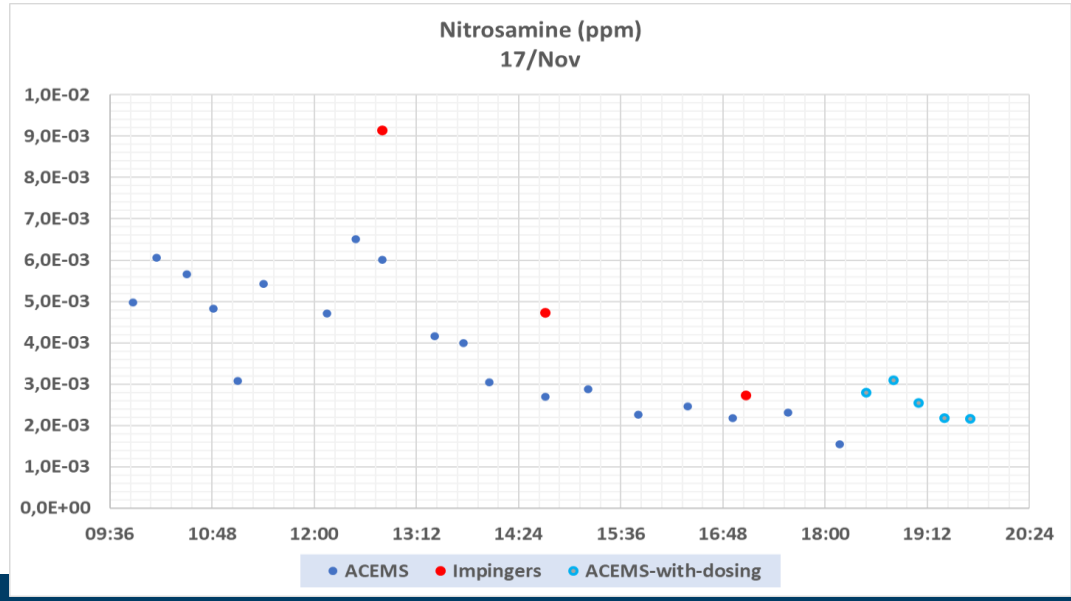


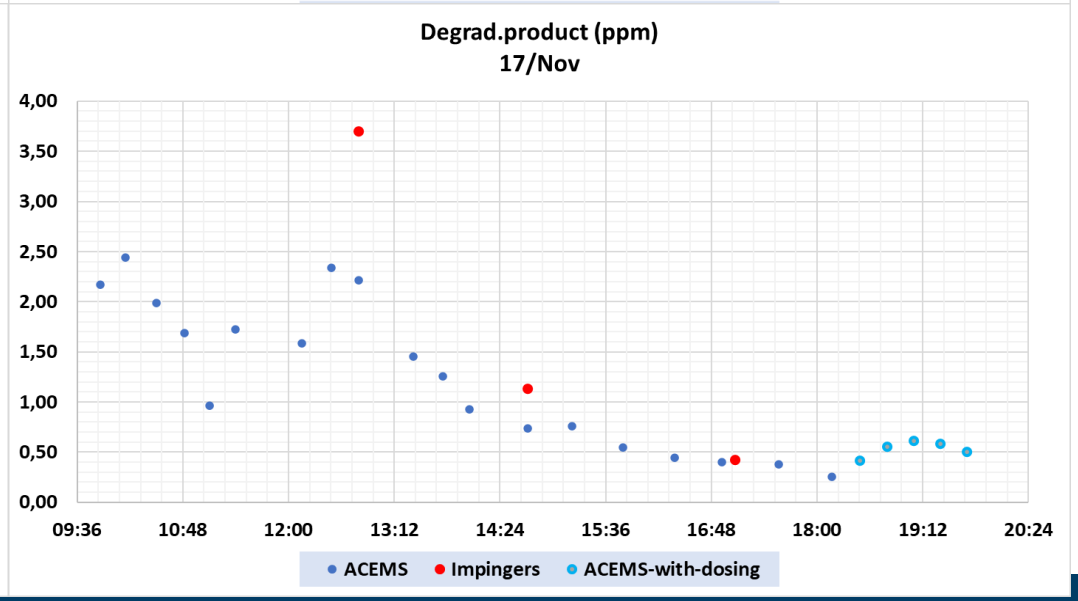


Dynamic state - increasing emissions + dosing (17/Nov-2022)

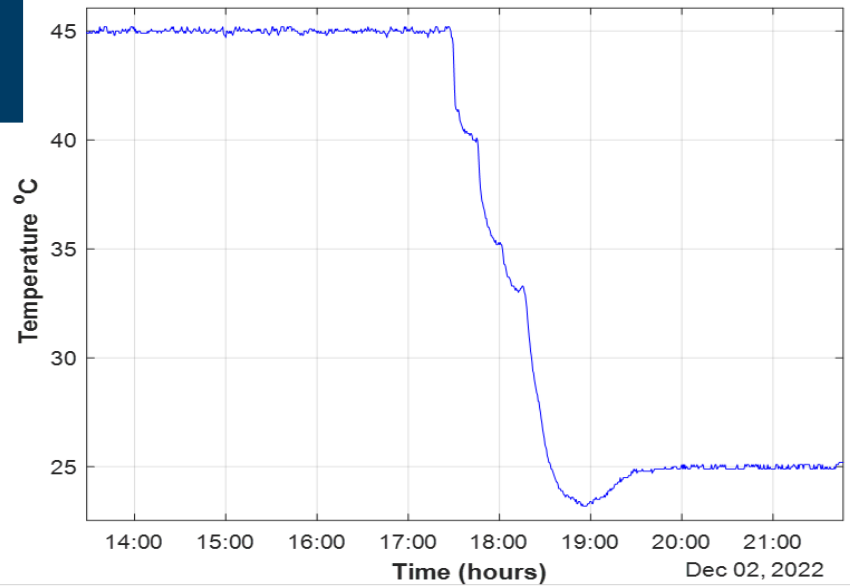


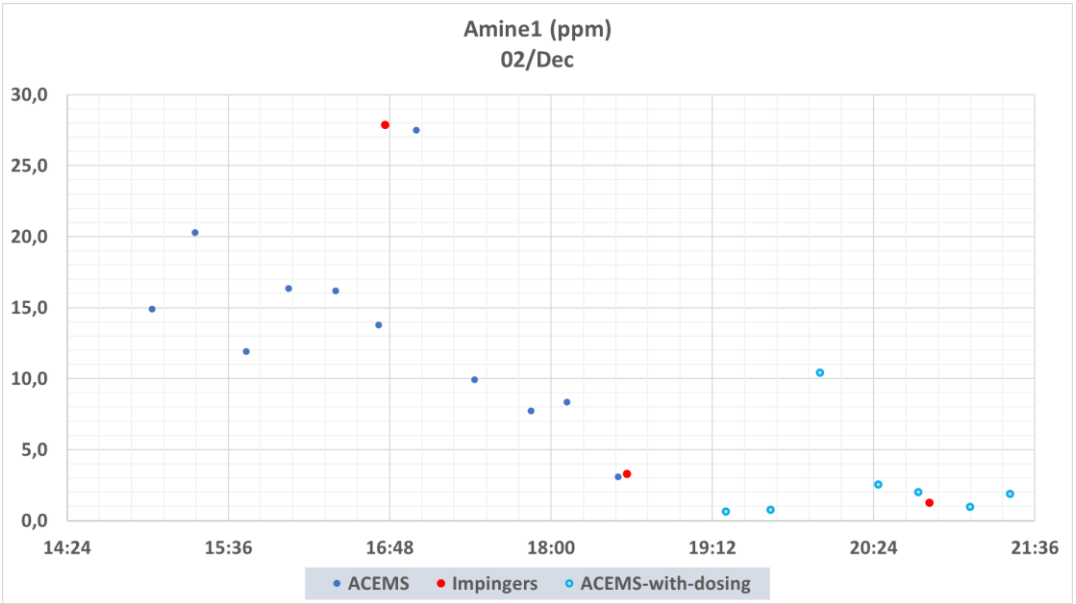


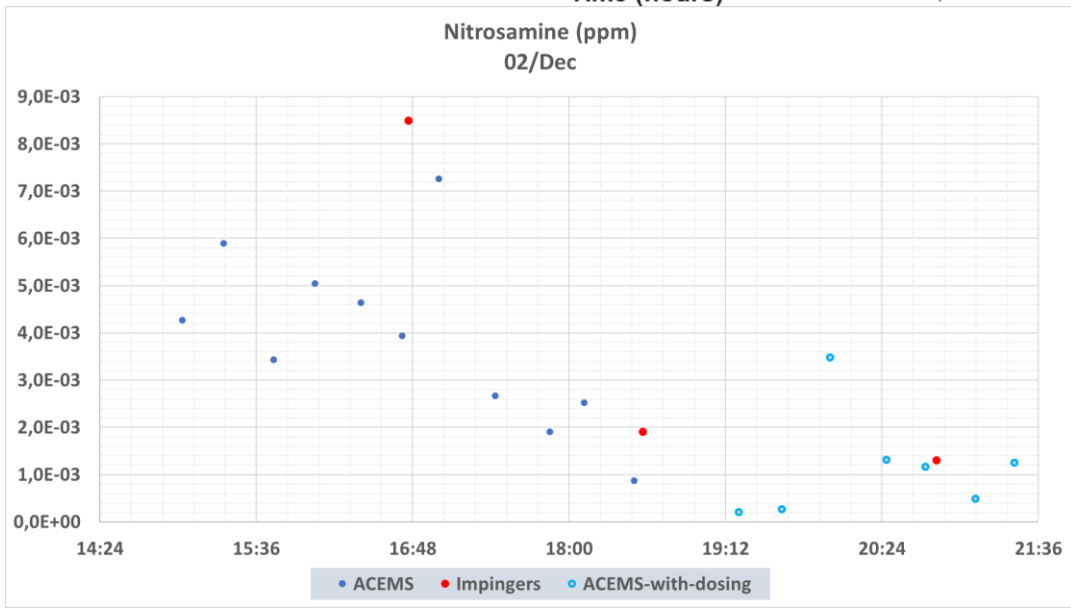


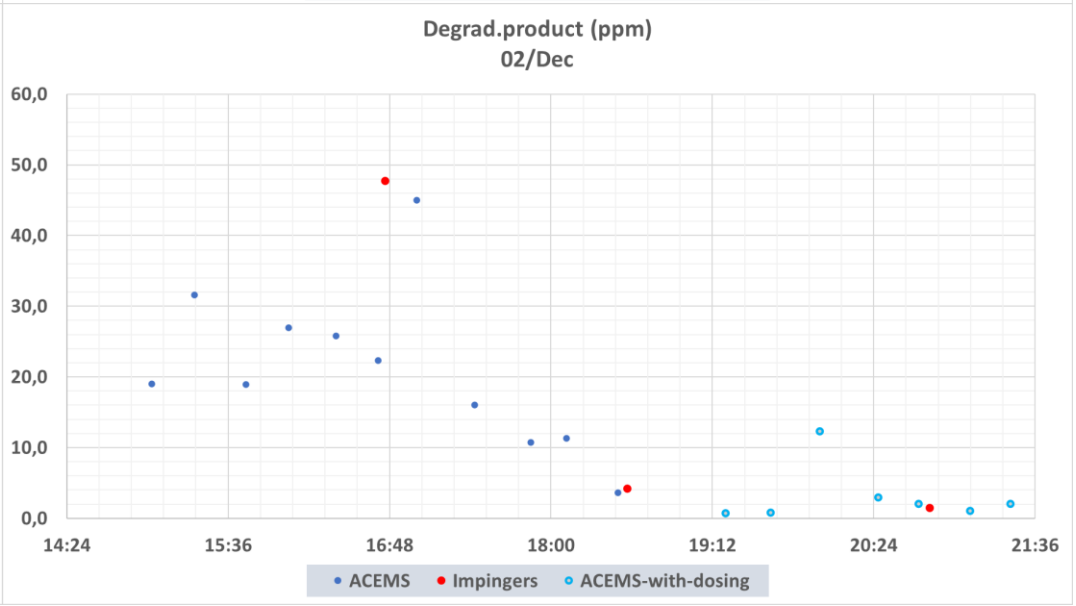


Dynamic state - increasing emissions + dosing (02/Dec-2022)









Summary

- SINTEF's ACEMS prototype has been proposed as one of the instruments with great potential for obtaining reliable samples of the both gas and water-wash analysis. The quality of the samples should suffice for in-depth study on emissions modelling, monitoring and control.
- However, demonstration results from previous ACEMS applications revealed that some aspects (sampling frequency, automation, widen trace analytes list, etc.) still need improvement
- In this sub-task the ACEMS prototype has been equipped with automation capability for both gas and water-wash sampling.
- Improvement of the sampling frequency has been successfully demonstrated by dosing.
- Further, the results obtained in this study for nitrosamine and the degradation product, even under dynamic conditions, indicated good potential to expand the ACEMS measurement components list. This will open coverage of a wider spectrum for the solvent components of concern in CESAR1.

Acknowledgements

1. **The SCOPE project:** This project is funded through the ACT programme (Accelerating CCS Technologies), ACT 3 Project No 327341. Financial contributions made by the Research Council of Norway (RCN), Rijksdienst voor Ondernemend Nederland (RVO), Department for Business, Energy & Industrial Strategy UK (BEIS), Forschungszentrum Jülich GmbH, Projektträger Jülich (FZJ/PtJ) Germany, Department of Energy (DoE) USA and Department of Science and Technology (DST) India are gratefully acknowledged. www.scope-act.org

2. **The REALISE project** has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884266;

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