A new compressor system based on a Resato gas booster replacing the Rix SA-models for filling whole air reference cylinders

university of groningen

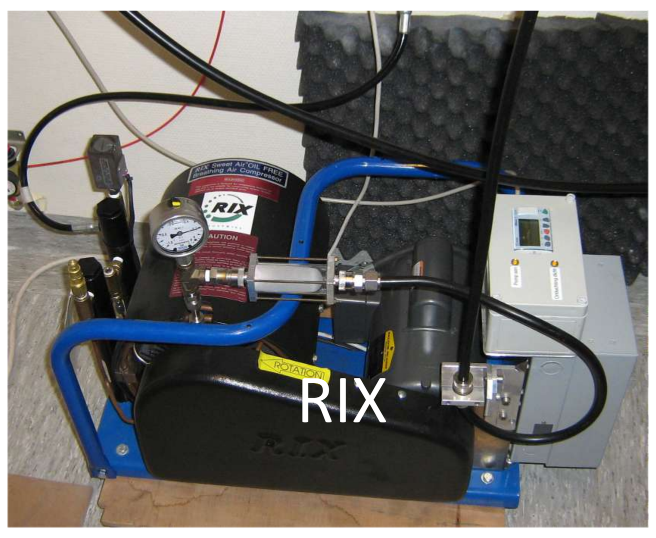
Hubertus A. Scheeren, Bert A. M. Kers, Huilin Chen

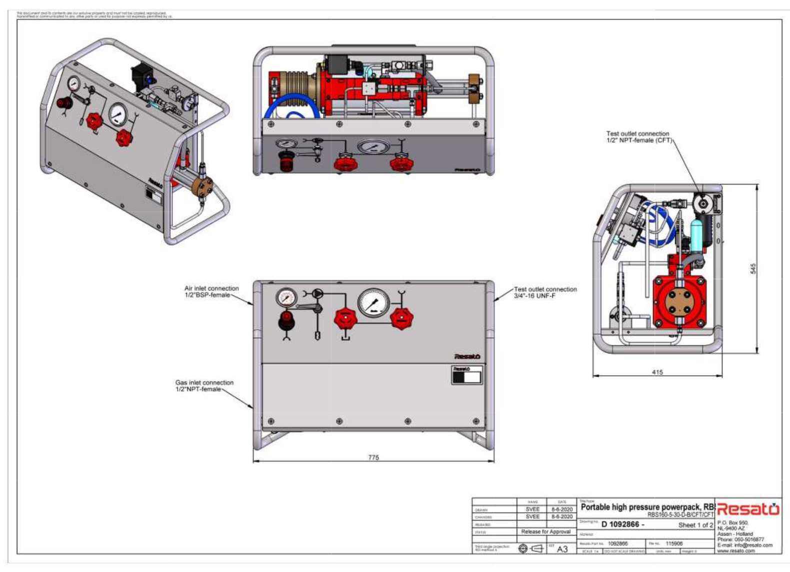
Center for Isotope Research (CIO), Energy and Sustainability Research Institute Groningen (ESRIG), University of Groningen

energy ESRIG sustainability

Motivation to go from Rix to Resato

For decades compressing ambient air into high pressure cylinders to serve as working standards in atmospheric science has been done by using a modified oil-free compressor system based on the three-stage dive compressors model SA-3 and SA-6 from Rix (Rix, Emeryville, California, USA) described in detail by *Mak & Brenninckmeijer* (1994).



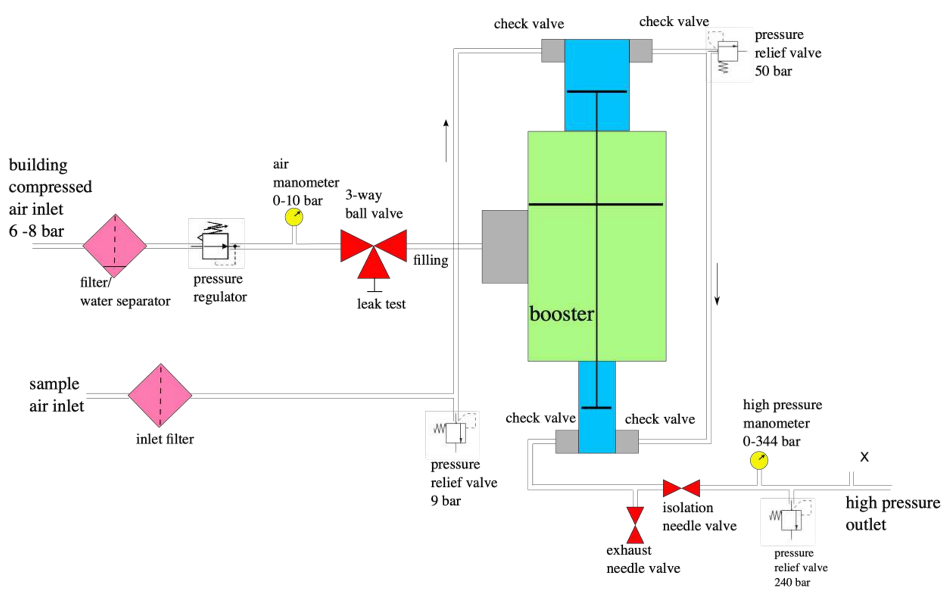


In 2017 the Rix company decided to stop production of their SA-3 and SA-6 oil-free compressors, apart from offering one last manufacturing run to serve the atmospheric science community.

In spite of its excellent performance over time, the compressor itself tended to be sensitive to regular failure due to mechanical stress and the breakdown of vital parts. This prompted us to seek for an alternative system which we found with Resato (Resato Int. B.V, Assen, The Netherlands).

Two-stage Resato air driven gas booster

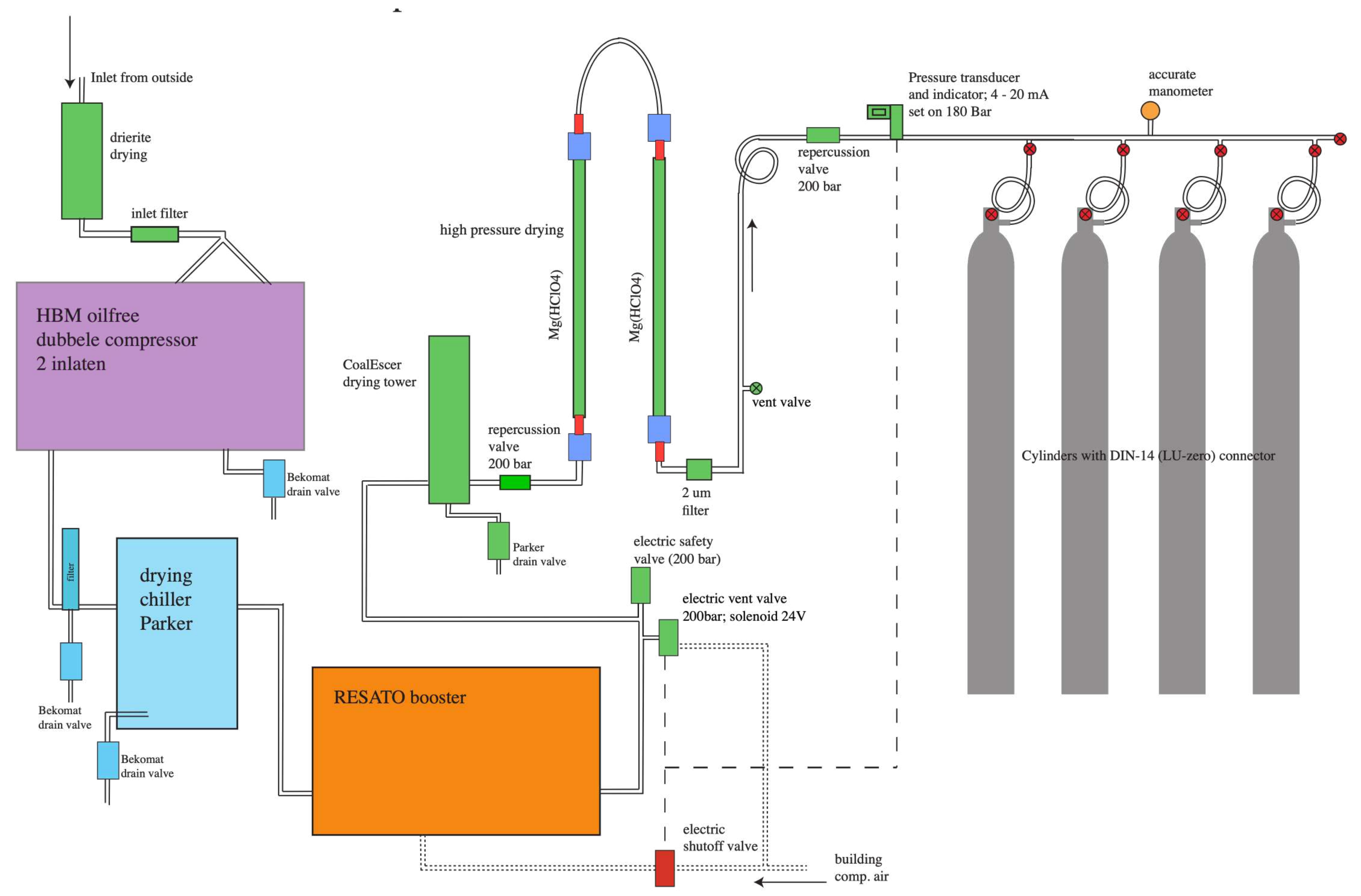
The heart of the new compressor system consists of a two-stage Resato air driven gas booster unit type RBS-160-5-30-D-B.



Working conditions for the booster unit

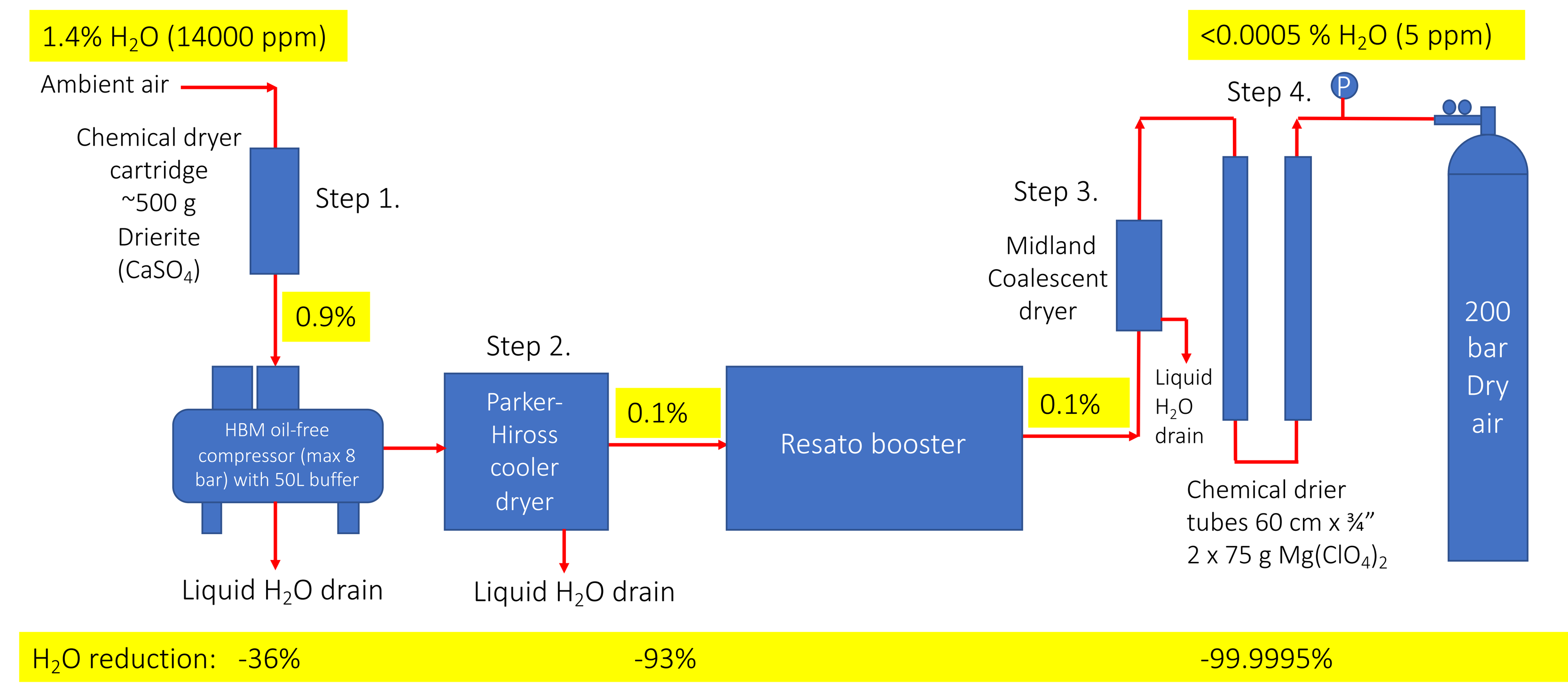
- A minimal sample air inlet pressure of 2 bar is required (optimal 4-5 bar), which can be provided by any oil-free commercial compressor with a 50 L (or larger) pressure tank serving as a buffer volume.
- The Resato booster uses standard laboratory compressed air (+2 bar higher than the sample air pressure up to max. 8 bar) as driver gas and can compress air up to max. 210 bar.
- The booster compresses by a factor of 1:5/1:30 (first and second stage) until it reaches a maximum set pressure, e.g. 200 bar.
- The valve seals are made of Teflon® (PFTE) or Viton® (FKM) and the high pressure piston seals are PFTE-based.

Set-up of the new cylinder filling station



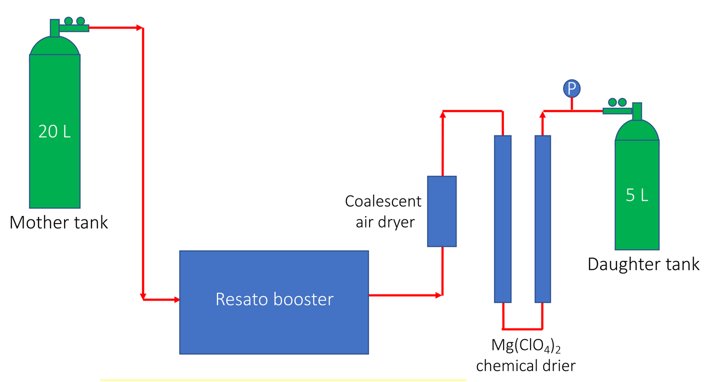
Water removal steps

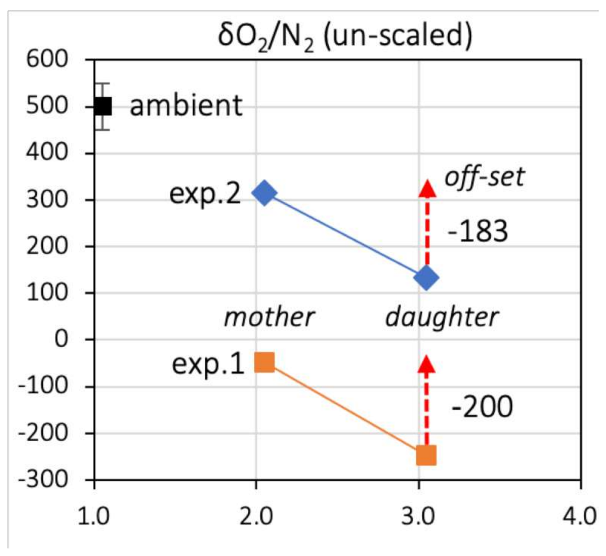
The drying steps are largely similar to our earlier Rix setup using chemical traps and coalescence towers to remove water, with the addition of a cryogenic cooler dryer after the first compression stage.



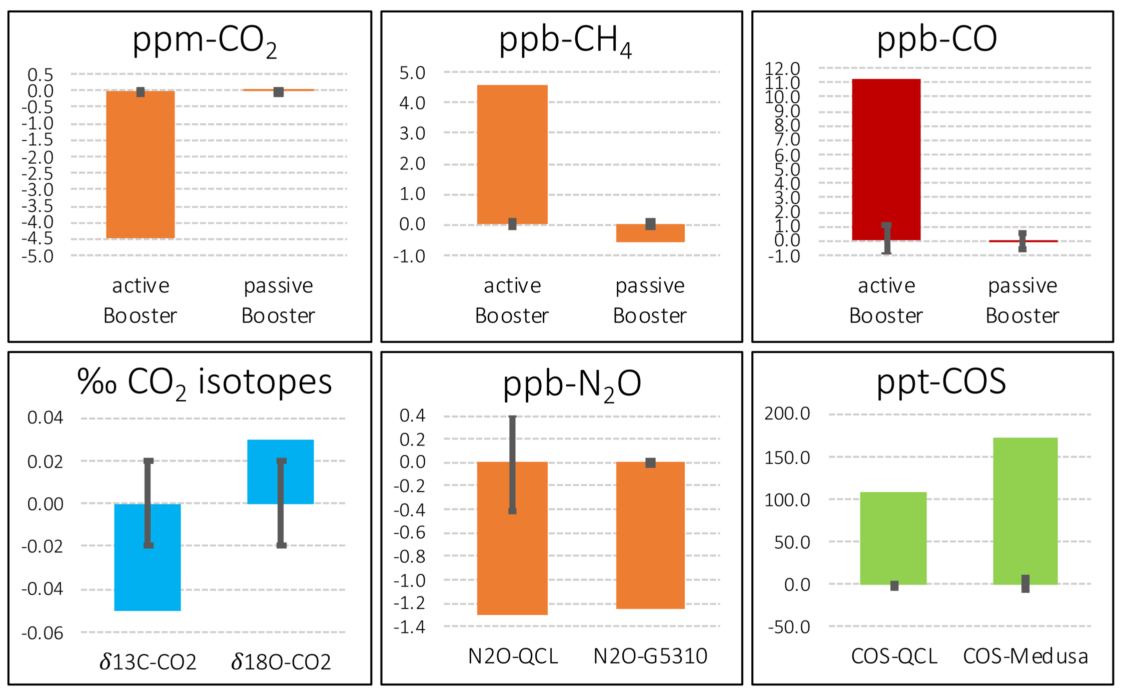
Testing the sample stability of the Resato compressor system

We have tested the sample stability of the our compressor system by comparing the composition of a "Mother tank", containing compressed ambient air or nitrogen, with a "Daughter tank".





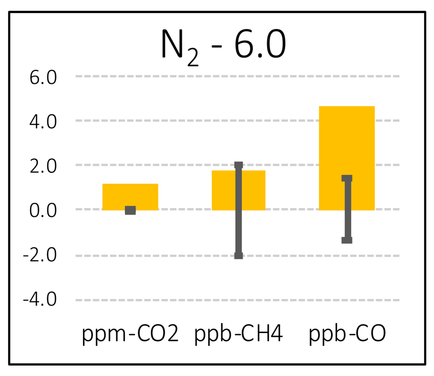
The Daughter was made by compressing the Mother air into a second cylinder ("active Booster"), or by flushing it through the booster in passive mode ("passive Booster").



Sample integrity tests for the $\delta O_2/N_2$-ratio show a negative off-set of around 200 per meg (set against ambient ratios of 500±50 per meg (un-scaled)). Exp. 1: air from 20 L Mother cylinder (130 bar) is compressed into a 5 L Daughter cylinder (40 bar). Exp. 2: the whole volume of a 10 L Mother (100 bar) is compressed into a 10 L Daughter, leaving <5 bar behind to minimalize the possibility of fractionation (which was not found). Measurements were performed at the CIO with a Dual-Inlet Isotope-Ratio Mass-Spectrometer (*Nguyen et al.*, 2022).

The top panel compares the sample stability of the Resato booster in the active high compression mode and in the passive mode for CO_2, CH_4, and CO (measured with a Picarro CRDS G2401). The error bars denote the measurement precision and the color bar depicts the difference between the Daughter and Mother air samples.

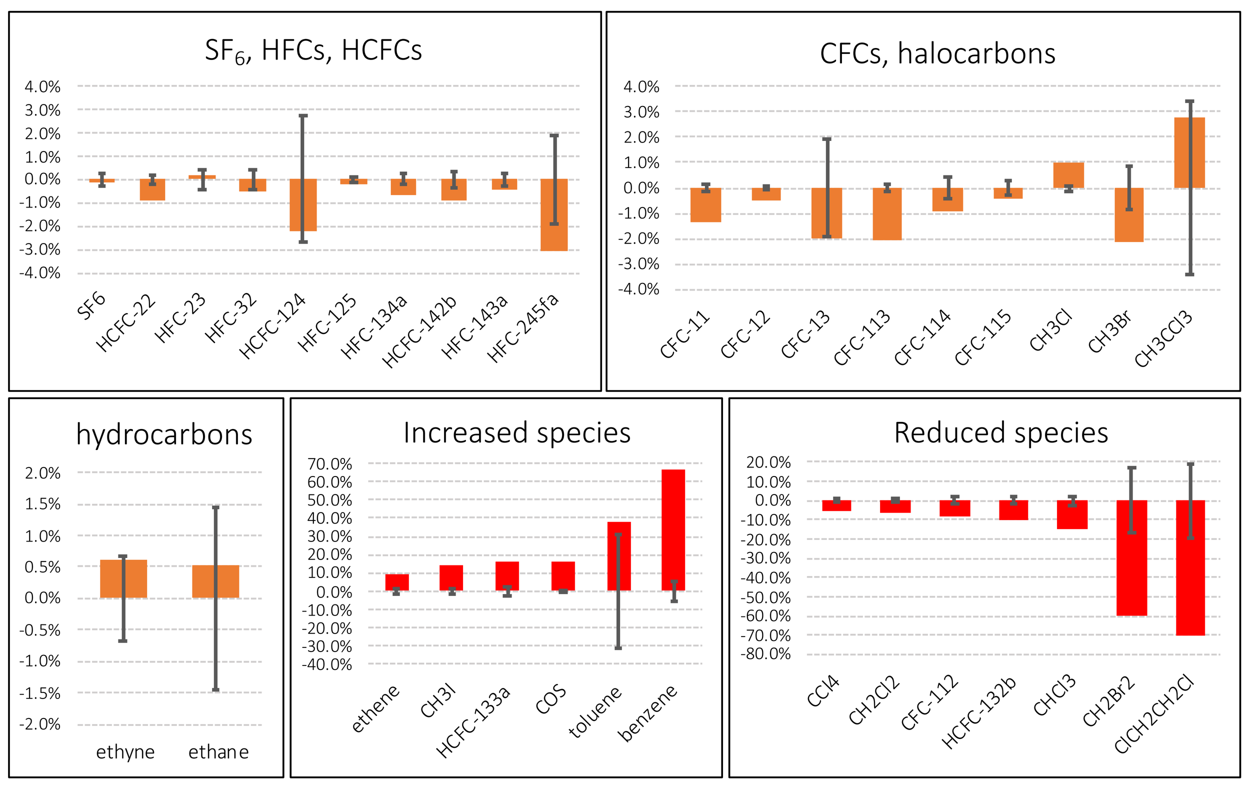
The lower panel shows results for stable isotopes of CO_2 (measured with an Aerodyne dual-laser absorption spectrometer (*Steur et al.*, 2021)), for N_2O and COS from two experiments (N_2O measured with a Picarro CRDS G5310 and an Aerodyne quantum cascade laser spectrometer (QCL), courtesy of Dr. Steven van Heuven, CIO-RUG), and COS measured with the QCL and on a Medusa GC-MS system from Bristol University (reference below). The biases are most likely related to outgassing (or absorption) inside the Resato booster during compression. During operation the Booster reaches temperatures around 60-70 ºC on the outer surface. When filling the Daughter tank through the Resato booster in the passive mode there was no bias detected.



This graph shows the bias induced by the Booster when compressing N2 (6.0) from a 40 L tank into a 5 L cylinder. We find that mostly CO is enhanced. CO_2 and CH_4 are measured near their detection limit and show no significant change.

Sample stability for a selection of halocarbons, NMHCs, CFCs, HFCs, HCFCs, and COS (carbonyl sulfide) from analyses on the Medusa GC-MS system (*Miller et al.*, 2008) performed by and courtesy of Dr. Angelina Wenger at Bristol University (School of Chemistry).

The error bar denotes the relative sample measurement precision (in %) and the color bar the relative difference between the (n=3) samples taken from the Daughter and the Mother tank (in %). We find that many trace gas species show no significant bias, while some increase significantly in the Daughter tank, e.g. CH_3I (+15%), COS (+17%), benzene (+66%). Some species are significantly reduced in the Daughter tank samples such as $CHCl_3$ (-15%), CH_2Br_2 (-60%), and $ClCH_2CH_2Cl$ (-70%).



Conclusions

- We have developed a new tank filling system to replace our Rix based system for ambient air reference cylinder up to 200 bar.
- The system is based on a Resato two-stage booster and requires an additional oil-free first stage compressor (to be defined by the user).
- We tested the sample integrity of the high compression part on a suit of trace gases which include GHGs, VOCs, hydrocarbons, halocarbons, the O_2/N_2-ratio, and isotopes of CO_2.
- We found tolerable biases of -1% for CO_2, +9% for CO, -0.4% for N_2O, -0.5% for $\delta^{13}C$-CO_2, and +2% for $\delta^{18}O$-CO_2.
- Trace gas species with a significant bias include COS (+17-24%) and $\delta O_2/N_2$ (-40%).

References

Mak, J., C.M. Brenninkmeijer, Compressed Air Technology for Isotopic Analysis of Atmospheric Carbon Monoxide, Journal of Atmospheric and Oceanic Technology, Vol. 11, No. 2, pp 425-431, April 1994.

Miller, Benjamin R., Ray F. Weiss, Peter K. Salameh, Toste Tanhua, Brian R. Greally, Jens Mühle, and Peter G. Simmonds, Medusa: A Sample Preconcentration and GC/MS Detector System for in Situ Measurements of Atmospheric Trace Halocarbons, Hydrocarbons, and Sulfur Compounds, *Anal. Chem.* 2008, 80, 5, 1536–1545, https://doi.org/10.1021/ac702084k, 2008.

Nguyen, L. N. T., Meijer, H. A. J., Van Leeuwen, C., Kers, B. A. M., Scheeren, H. A., Jones, A. E., Brough, N., Barningham, T., Pickers, P. A., Manning, A. C., and Luijkx, I. T. (2022). Two decades of flask observations of atmospheric (O_2/N_2), CO_2, and APO at stations Lutjewad (the Netherlands) and Mace Head (Ireland), and 3 years from Halley station (Antarctica). *Earth System Science Data*, *14*(2), 991-1014. https://doi.org/10.5194/essd-14-991-2022.

Steur, P. M., Scheeren, H. A., Nelson, D. D., McManus, J. B., and Meijer, H. A. J.: Simultaneous measurement of $d^{13}C$, $d^{18}O$ and $d^{17}O$ of atmospheric CO_2- performance assessment of a dual-laser absorption spectrometer, *Atmos. Meas. Tech.*, 14, 4279– 4304, https://doi.org/10.5194/amt-14-4279-2021, 2021.

Resato International B.V., Assen, The Netherlands, www.resato.com
Contact person: Jur Immink, Area Sales Manager Resato High Pressure Technology (jurimmink@resato.com)
Phone: +31 (0)50 501 6877 | +31 (0)62 960 30 45