OUR KNOWLEDGE
IS YOUR SUCCESS

Application note:

Comparison of MACView® Ethylene Oxide (EtOx) Gas Analyzer (EtOx GA) by Thermal Desorption Gas Chromatograph Mass Spectrometer (TD-GC-MS)

Test of suitability and performance for use of human safety and climate control

Structure of the document: In this document 4 subjects are explained:

23th of June 2018

J.K. Boerman

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE IS YOUR SUCCESS

Title	Application note: Comparison of MACView® Ethylene Oxide (EtOx) Gas Analyzer (GA-EtOx) by Thermal Desorption Gas Chromatograph Mass Spectrometer (TD-GC-MS)
Authors	J.K. Boerman
Company	Environmental Monitoring Systems (EMS) B.V.
Date of publication	23th of June 2018
Version	V1.2 (Final version)
Confidentiality	No
Approved by	J.K. Boerman
Review	Internally-reviewed
Name reviewer	L. van der Hart
Client	-

Environmental Monitoring Systems (EMS) B.V.
Spastraat 30
NL - 4697 RZ SINT-ANNALAND
Phone: +31 (0)166-657200
Fax: +31 (0)166-657210
E-mail: info@macview.nl
Internet: www.macview.eu

OUR KNOWLEDGE
IS YOUR SUCCESS

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE
IS YOUR SUCCESS

1 Introduction

This document explains in a short way the performance of the MACView® EtOx Gas Analyzer for the reliable measurement of the toxic gas Ethylene oxide.

Ethylene oxide, called oxirane by IUPAC, is an organic compound with the formula C2H4O. It is a cyclic ether and the simplest epoxide: a three-membered ring consisting of one oxygen atom and two carbon atoms. Ethylene oxide is a colourless and flammable gas with a faintly sweet odour. Because it is a strained ring, ethylene oxide easily participates in a number of addition reactions that result in ring-opening. Ethylene oxide is isomeric with acetaldehyde and with vinyl alcohol.

The reactivity that is responsible for many of ethylene oxide's hazards also make it useful. Although too dangerous for direct household use and generally unfamiliar to consumers, ethylene oxide is used for making many consumer products as well as non-consumer chemicals and intermediates. These products include detergents, thickeners, solvents, plastics, and various organic chemicals such as ethylene glycol, ethanolamines, simple and complex glycols, polyglycol ethers, and other compounds.

Although it is a vital raw material with diverse applications, including the manufacture of products like polysorbate 20 and polyethylene glycol (PEG) that are often more effective and less toxic than alternative materials, ethylene oxide itself is a very hazardous substance. At room temperature it is a flammable, carcinogenic, mutagenic, irritating, and anaesthetic gas.

As a toxic gas that leaves no residue on items it contacts, ethylene oxide is a surface disinfectant that is widely used in hospitals and the medical equipment industry to replace steam in the sterilization of heat-sensitive tools and equipment, such as disposable plastic syringes. It is so flammable and extremely explosive.

Ethylene oxide is in the logistic chain a potential risk for humans due to the fact that the ethylene oxide is left as residue inside boxes, packages, warehouses and truck loadings. Moving and unpacking creates short term exposure levels. Ethylene oxide is known as a carcinogenic substance, so avoiding contact between this substance and humans is a critical point of attention. It is therefore important that employees are well protected and regularly monitored.

This report investigates the possibilities for use of the MACView® EtOx Gas Analyzer in these applications to provide reliable and consisting measurements.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

2 Methods

2.1 The MACView® EtOx Gas Analyzer

The MACView® EtOx Gas Analyzer is a selective gas measurement device that measure the ethylene oxide concentrations coming from ambient and environmental exposure up to ppb-range concentration to integrate precisely the total exposure to humans across time. The total concentration across time from the measurement can be directly compared with the Maximum Allowed Concentrations for humans of the substance ethylene oxide. Results were acquired via a web based portal (http://www.mymacview.com) of EMS.

In this this application note we explain and discuss the results of a set of comparison measurements of the MACView® EtOx Gas Analyzer against a Thermal Desorption Gas Chromatograph Mass Spectrometer (TD-GC-MS). The MACView® EtOx Gas Analyzer (indicated as EtOx-GA).

2.2 Measurement set up

The measurement setup was constructed enbling the EtOx-GA to sample test gas from a gas stream without pressure build-up. The gas stream was made from pure calibration gas and certified standard gas (3.5 ppm ethylene oxide, balance air, Messer Group). A gas mixer consisting of programmable multiple range mass-flow controllers was used to create a flow of 200 ml/min, which was transported using 1/8” tubing and a split to the EtOx-GA and the TD-GC-MS. The gasflow was humidified by approximately 50% humidified balanced air from a bottle, at 22°C. The EtOx-GA autonomously samples about 100 ml/minute continuously, and by releasing the rest of the gas stream through a 1/8” tubing. The sampletime is adjusted from 15 minutes to 20 minutes per measurement, too flush the 1/8” lines carefully and to prevent measurement errors. The EtOx-GA was calibrated with the 3.5 ppm calibration gas, on a calibration setpoint of 1000 ppb, containing 50% humidified air @22°C.

2.3 Verification of the ethylene oxide measurements

Ethylene oxide was monitored and verified using a TD-GC-MS (Thermal Desorption Gas Chromatograph Mass Spectrometer) which was calibrated before use with the 3.5 ppm ethylene oxide, balance air, Messer Group. The TD (Markes Series 2 Unity) samples periodically approximately 10 minutes gas from the T-piece split, from the 1/8” tubing after absorbing the ethylene oxide sample gas, it is analyzed by the GC-MS (Agilent 7890A with PortaPlot Q 30m. 0.32 mm diameter and Agilent 5975C triple axis). The TD-GC-MS produces approximately every 30 minutes a new measurement including absorption and desorption of the ethylene oxide.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE
IS YOUR SUCCESS

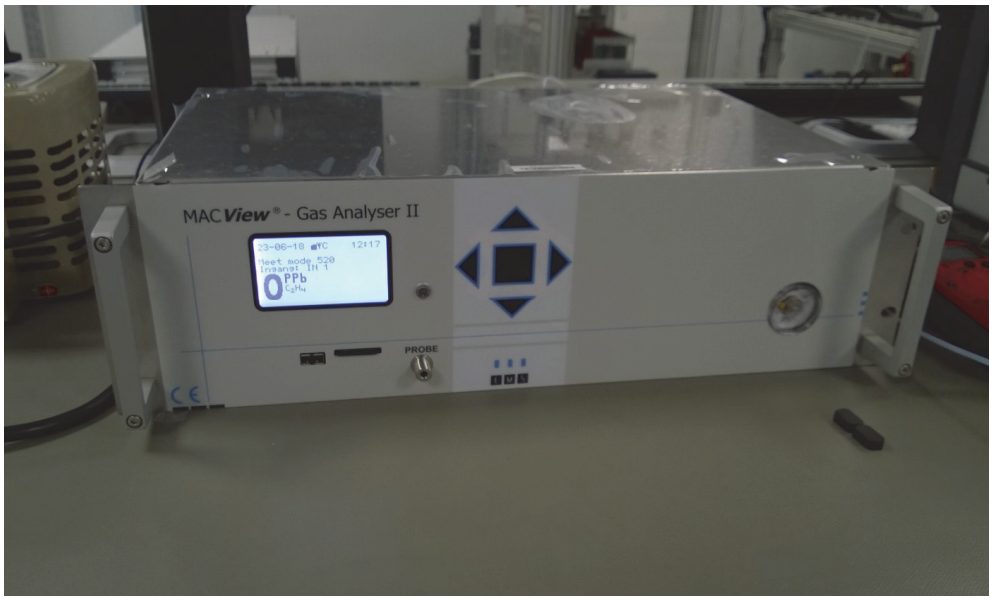

Figure 1: MACView® EtOx GA at test set up.

Figure 2: Thermal Desorption Gas Chromatograph Mass Spectrometer (TD-GC-MS) at the test set up.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

WWW.MACVIEW.NL

2.4 Verification of the ethylene oxide measurements

In this session the gas mixing system produces the following schedule of gas concentrations for the measurement procedure. Each step was maintained for 2 hours.

Step	Ethylene oxide [ppb]	Water [%]	Duration [minutes]
1	0	50	120
2	1000	50	120
3	800	50	120
4	600	50	120
5	400	50	120
6	200	50	120
7	100	50	120
8	50	50	120
9	25	50	120
10	0	0	120

After the above measurement procedure the EtOx-GA is checked manually by feeding direct 1000 ppb of calibration gas from the MFC mixing system to check whether the calibration is still in range.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE IS YOUR SUCCESS

Results

2.5 Measurement procedure

The data was gathered from the analyzers and processed. Attention of data gathering is the synchronisation of the two analyzer systems. The data is presented based on data and time stamps. For the EtOx-GA every 1st and 6th data point of the measurements within 1 concentration were excluded from the correlations, because there were unwanted errors due to the gas mixing systems synchronisation related to the analyzers. For the TD-GC-MS, every 1st and 4th data point of the measurements within 1 concentration were excluded from the correlations.

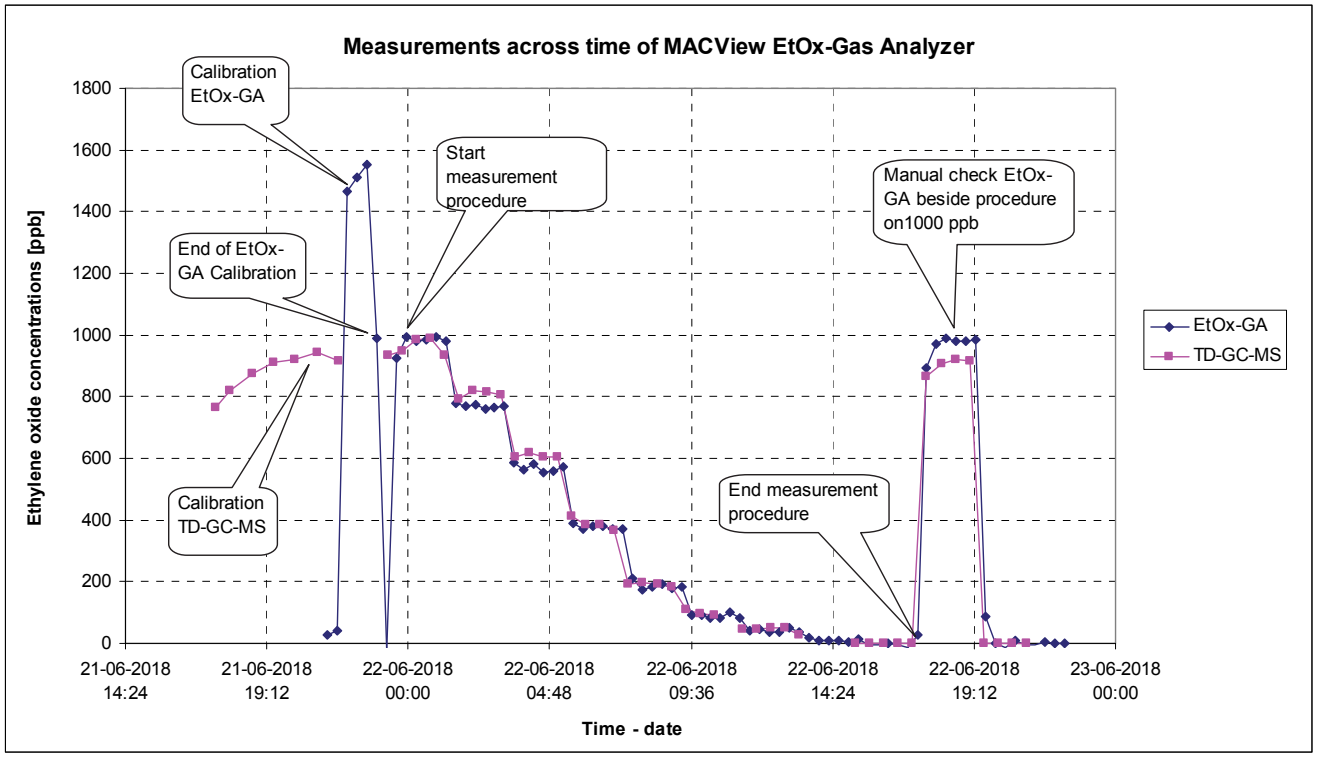

Figure 3: Typical raw data of chronological procedure. Ethylene oxide concentrations run with intervals of two hours per concentration. Pattern of ethylene oxide concentrations coincide very well. Procedures: a.) Calibration of TD-GC-MS with EtOx. b.) Calibration of EtOx-GA with EtOx. c.) Procedure measurement of EtOx gas exposure with 1000 – 800 – 600 – 400 – 200 -100 -50 - 20 - 0 ppb. d.) Manual check on EtOx-GA with 1000 ppb EtOx gas.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

2.6 Correlation graphs of Massflow Controllers

In the different correlation diagrams it became clear that the correlation graph between the TD-GC-MS and MFC is a slight more different behaviour when all data points are included or when only the most relevant error-free data points are chosen.

EtOx concentration [ppb]	Standard deviation [ppb] TD-GC-MS		Standard deviation [ppb] EtOx-GA	
	All data points	Point 2,3,4,5	All data points	Point 2,3
1000	26.6	1.8	27.0	6.0
800	12.5	1.6	6.1	5.1
600	6.2	9.2	11.7	10.8
400	19.5	4.6	7.0	4.8
200	6.2	3.0	13.3	7.2
100	11.4	4.7	7.3	8.6
50	1.4	1.5	5.8	6.9
20	12.3	-	5.2	3.2
Average standard deviation:	**12.0**	**3.8**	**10.4**	**6.6**

Figure 4: Overview of the standard deviations which show clearly that the transition between concentrations showed statistical differences.

In most correlation graphs the 20 ppb exposure shows serious differences according to accuracy and reproducibility. The TD-GC-MS is not possible to detect this concentrations except once that the transition occurred from 50 to 20 ppb. These concentrations are not a real target in this performance study. If these measurement ranges are more important, then other MFC's must be selected with different (10 times lower) concentrations. Reliable functioning of MFC's is usually only in the range of 10 – 90% of the measurement range of the MFC.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE
IS YOUR SUCCESS

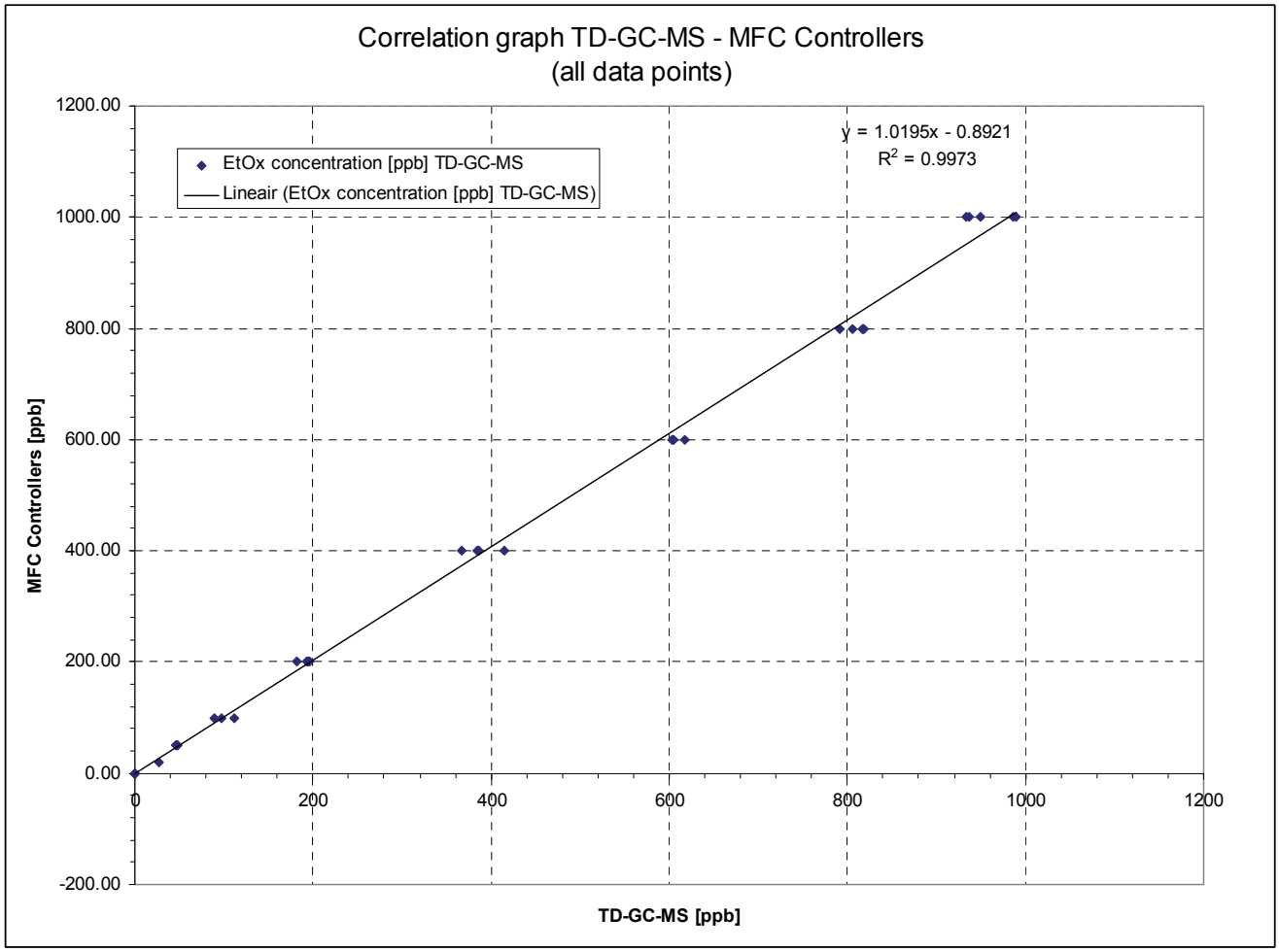

Figure 5: Results of measurement procedure, correlation graph TD-GC-MS against MFC Controllers, every data point is used and presented including the 1st and 4th data point from each single concentration.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

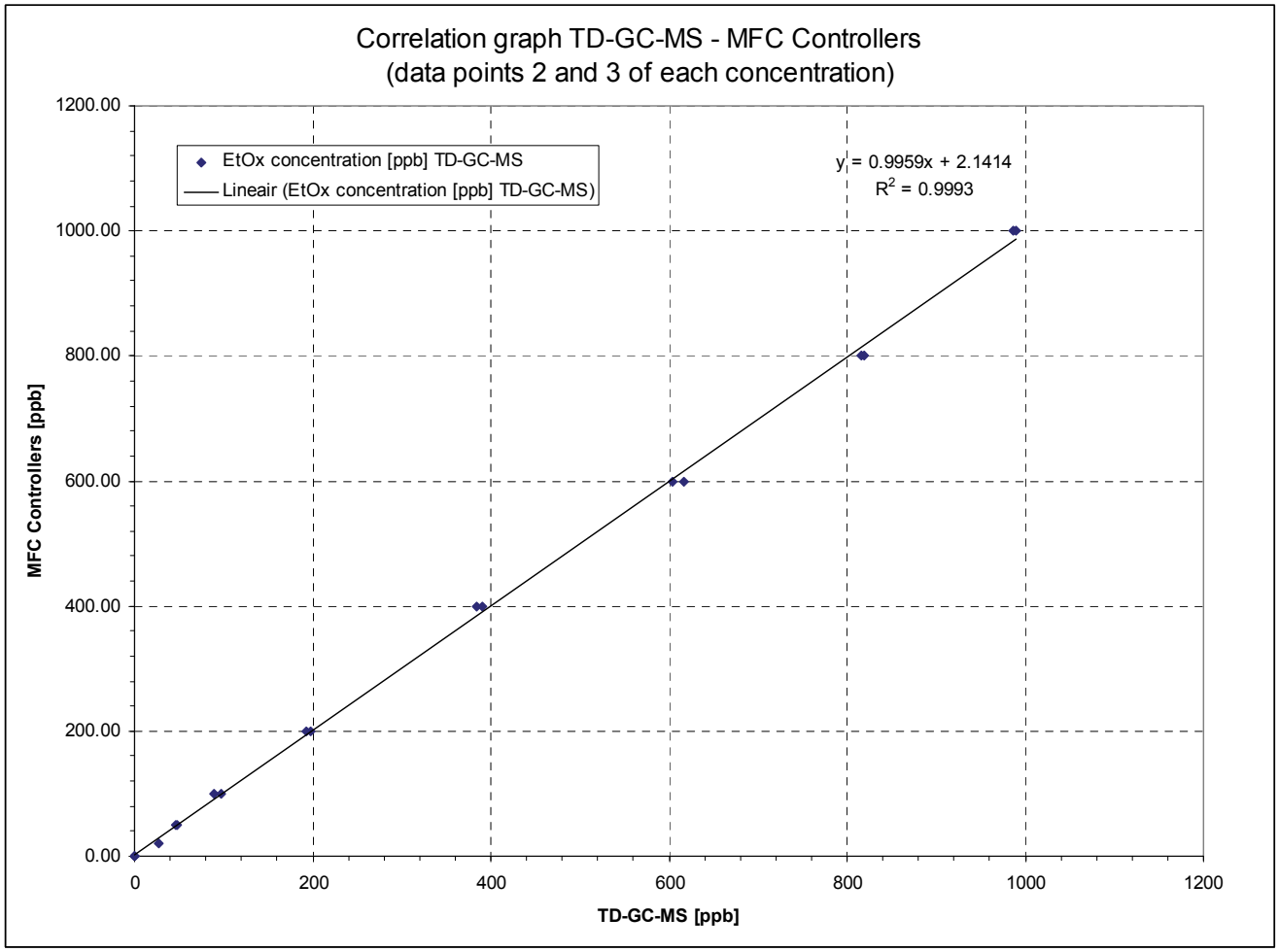

Figure 6: Results of measurement procedure, correlation graph TD-GC-MS against MFC Controllers, every 1st and 4th data point excluded from each single concentration, which results in a small increase of the r2.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

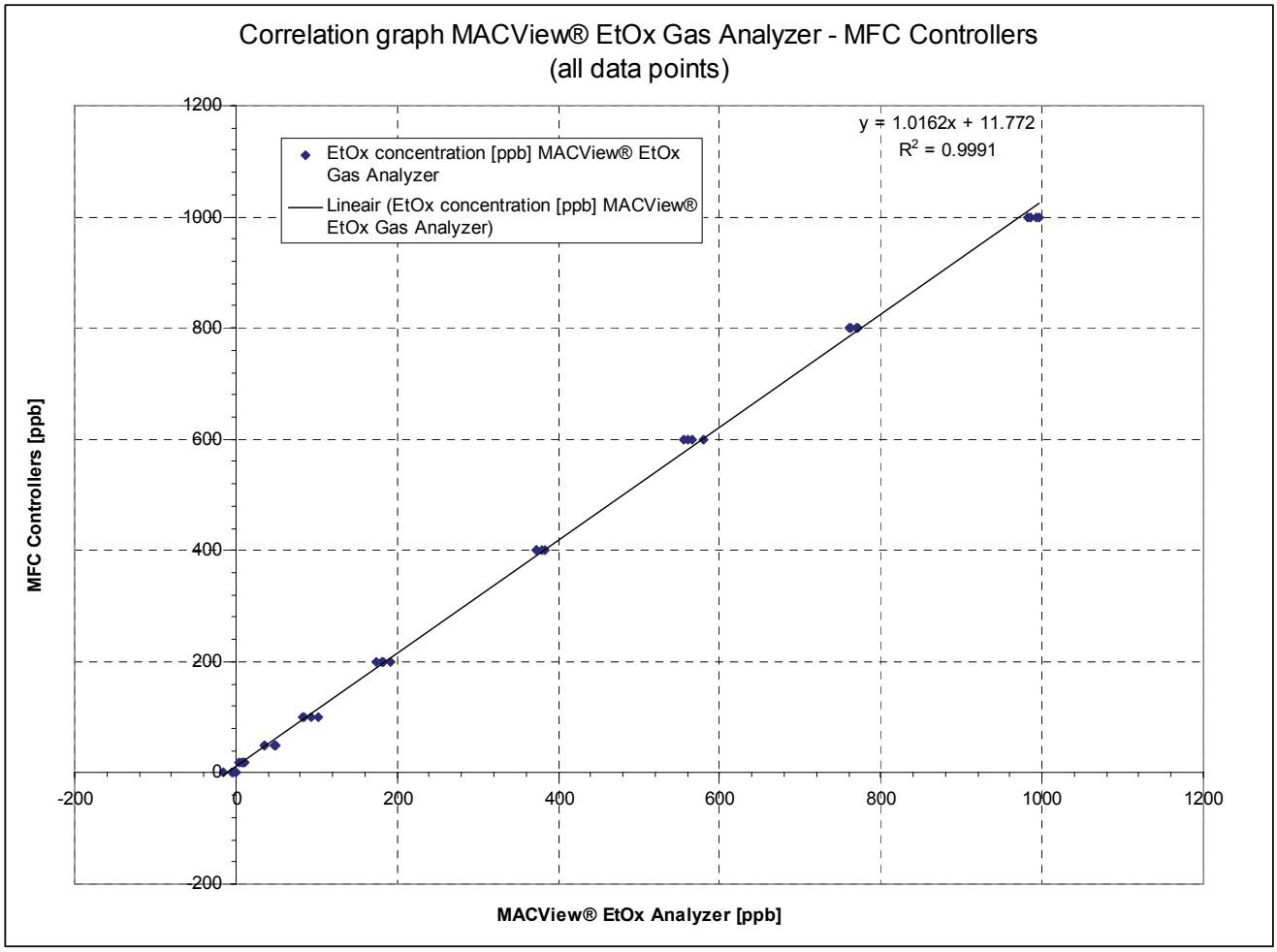

Figure 7: Results of measurement procedure, correlation graph EtOx-GA against MFC Controllers, every data point is used and presented including the 1st and 4th data point from each single concentration.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

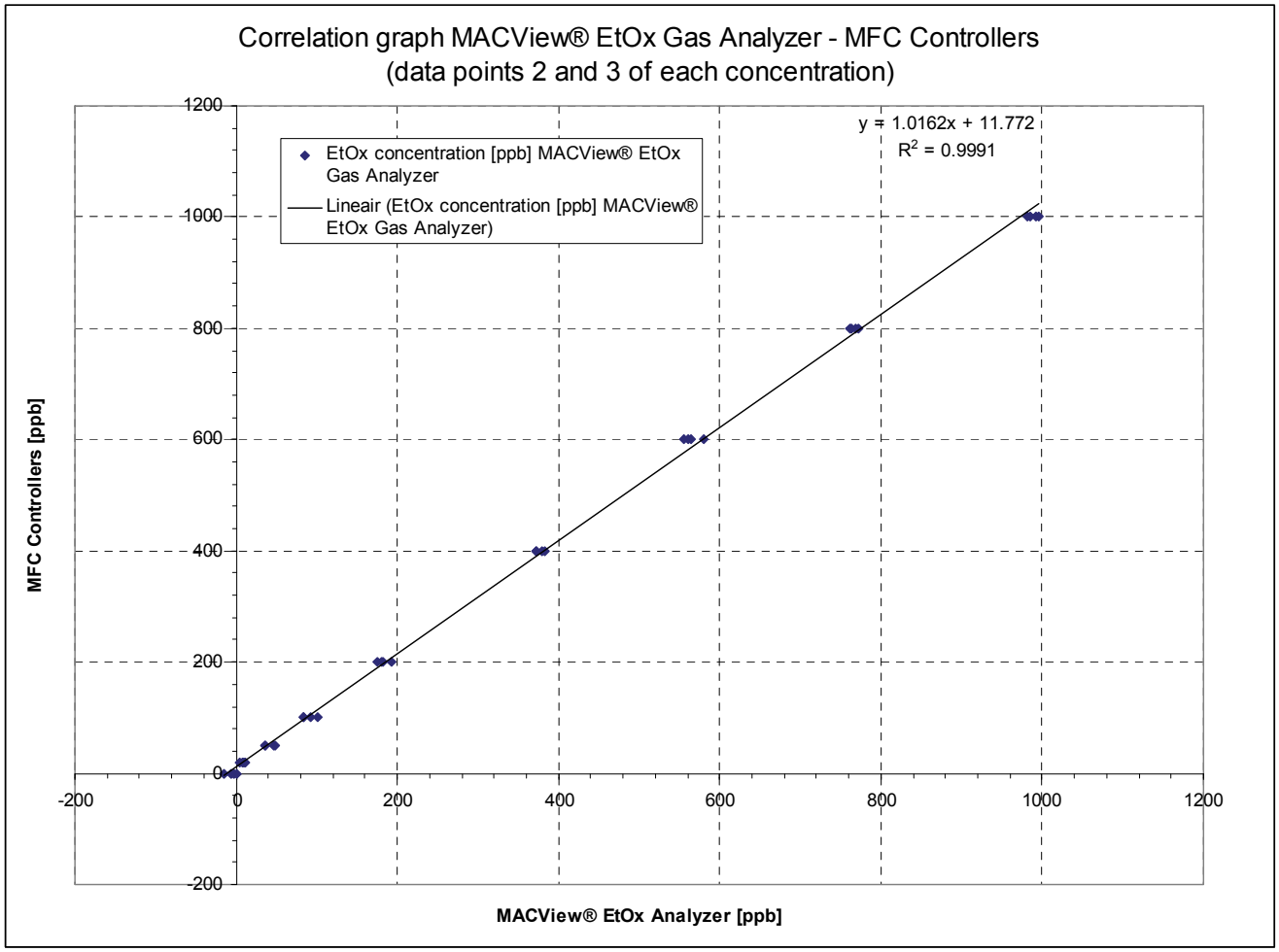

Figure 8: Results of measurement procedure, correlation graph EtOx-GA against MFC Controllers, every 1st and 4th data point excluded from each single concentration, which does not result in a change of slope or r2.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

OUR KNOWLEDGE IS YOUR SUCCESS

2.7 Correlation graphs of EtOx-GA and TD-GC-MS

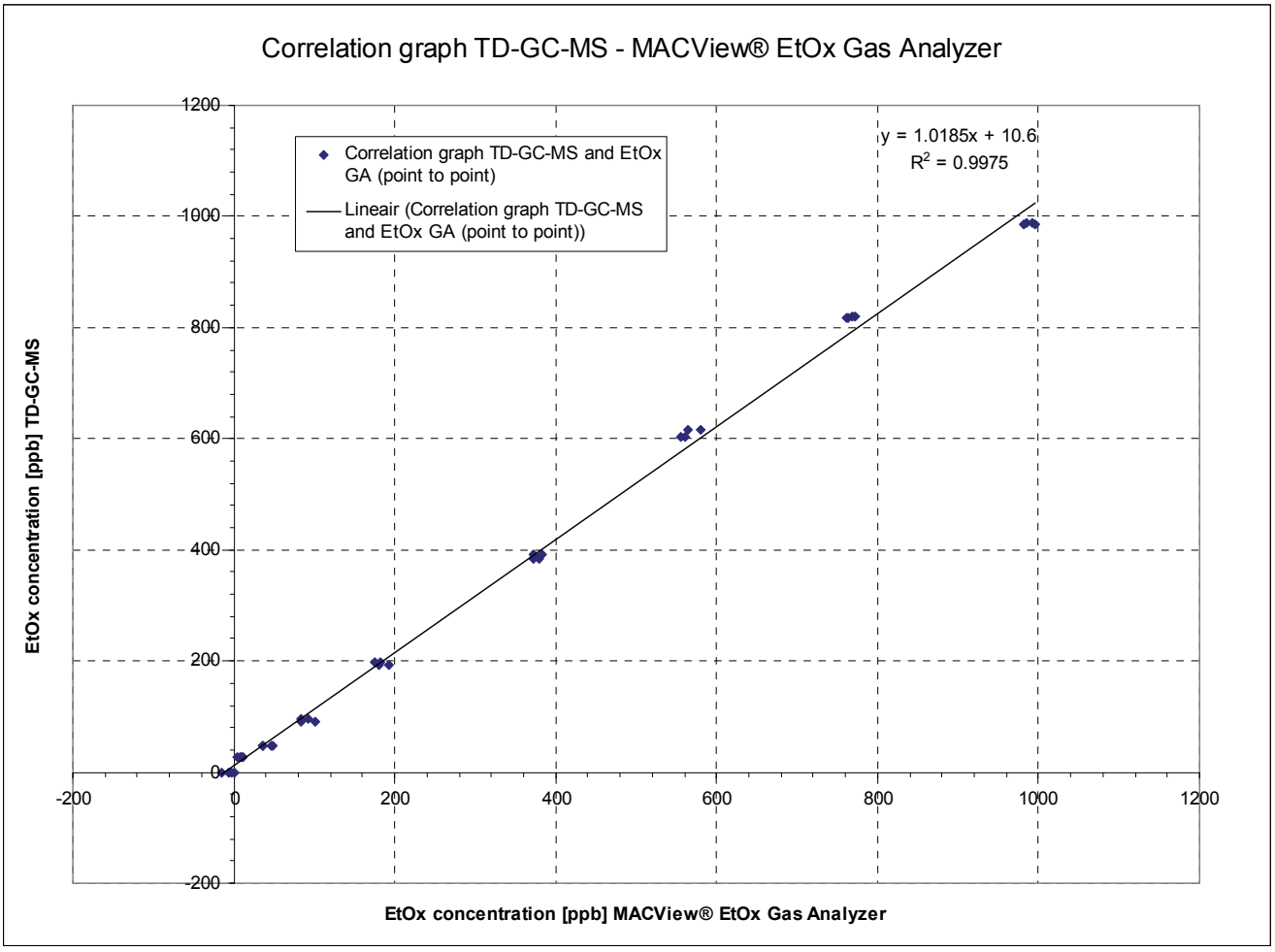

Figure 9: Results of the measurement procedure as correlation between the EtOx-GA with as reference the TD-GC-MS. On average standard deviation of EtOx-GA was 6.6 ppb and on the TD-GC-MS 3.8 ppb.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

3 Conclusions

The MACView® EtOx Gas Analyzer (EtOx-GA) was investigated on its performance and showed detection limits within the ppb range.

The reference ethylene oxide measurements using a Markes Thermal Desorption and Agilent Gas Chromatograph Mass Spectrometer, have a higher standard deviation, but need at least 30 minutes for 1 measurement.

Concluding from these tests we found that the Et-Ox-GA:

- Was easy to operate and to collect and remotely monitor data by the web portal.
- Can detect low levels of ethylene oxide (tested 20 – 1000 ppb).
- Requires between 15 and 20 minutes per measurement. Depending on the timing after a change of sampling point or gas, the first measurement value is often not stabilized, which is completely in line with the TD-GC-MS.
- In these test the standard deviation on the measurement range of 0-1000 ppb of the Et-Ox-GA was found on an average of 6.6 ppb.

From these tests we conclude that the MACView® EtOx Gas Analyzer is suited for precise and reliable measurement of ethylene oxide concentrations in packaging, warehouse and disinfection processing, for protection and monitoring of human health and safety. This makes the MACView® EtOx Gas Analyzer an excellent practical device for monitoring ethylene in storage and logistics of ethylene oxide gas concentrations.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl

4 References

W. Krämer (2006), "Method for the determination of ethylene oxide." German Social Accident Insurance, ISBN: 978-3-527-32818-5.

Pascal Gimeno et al. (2018), "Identification and quantification of ethylene oxide in sterilized medical devices using multiple headspace GC/MS measurement." Journal of Pharmaceutical and Biomedical Analysis, 5 September 2018, Pages 119-127 (In progress).

G. E. Burroughs et al. (1994), "Ethylene Oxide by Portable GC NIOSH Manual of Analytical Methods (NMAM)", NIOSH/DPSE Fourth Edition, 8/15/94.

Eklund BM et al. (2004), "Development and validation of a canister method for measuring ethylene oxide in ambient air." Environmental Science and Technology 2004 Aug 1; 38(15):4200-5.

Spastraat 30
4697 RZ Sint-Annaland

t +31 166 65 72 00
f +31 166 65 72 10

e info@macview.nl
I www.macview.nl