

Technical Report

Analysis of Volatile Organic Compounds in the Environment Using the Restore Function of TD-GC/MS

Naru Maruoka¹, Masato Takakura¹, Akira Aono¹

Abstract:

Measuring the concentration of volatile organic compounds (VOCs) in the air serves as a means of determining air pollution and is used to monitor pollution in a wide variety of environments, such as within manufacturing plants, urban areas, and indoor environments. VOC measurements are commonly performed using a thermal desorption-gas chromatograph mass spectrometer (TD-GC/MS). To reduce the risk of analysis failures due to the time-consuming process of sampling the atmosphere, multiple tubes are typically used for backup sampling or samples are re-analyzed using a TD restore function. However, previous TD restore functionality did not control the sample line temperature adequately, which made it difficult to simultaneously restore compounds with a wide range of low and high boiling points. To solve such problems with TD functionality, the authors developed a TD system (TD-30R) that can adjust the sample line temperature as appropriate for each analytical process step. This report describes the results from studying the appropriate sample line temperature for each section (trap tube cooling/desorption temperatures, sample tube desorption temperature and flowrate, and joint, valve, and transfer line temperatures) in terms of optimizing analytical conditions for simultaneously measuring VOCs with a wide range of low and high boiling points using TD restore functionality. The report also describes the results from using the optimized conditions to simultaneously analyze, with high sensitivity and a high restoration efficiency, a wide range of low and high boiling-point VOCs in the air inside an actual indoor environment.

Keywords: GC/MS, TD, restore, VOCs, TO-17, and air pollution

1. Introduction

Measuring the concentration of volatile organic compounds (VOCs) in the air serves as a means of determining air pollution and is used to monitor pollution in a wide variety of environments. Method TO-17, specified by the United States Environmental Protection Agency (U.S. EPA), is known as the most common method for analyzing VOCs. Method TO-17 actively samples the air (adsorbs VOC components from the air by pumping the air through an adsorption tube) and then analyzes the VOCs in the tube using a thermal desorption-gas chromatograph mass spectrometer (TD-GC/MS). However, because the method requires a long time for sampling the atmosphere, multiple tubes are typically used to collect back samples or TD restore functionality is used to reduce the risk of failing to analyze the VOCs.

The TD restore function thermally desorbs the sample gases trapped inside the sample tube and then restores the split sample gases in the tube before injection into the GC/MS system. Specifically, as shown in Fig. 1, volatile components thermally desorbed from the sample tube are trapped in a trap tube (Fig. 1 (1)). Then the trap tube is heated to desorb the components and inject them into the column. The components in the sample gases that were split off before injection into the column are then trapped again in the sample tube (Fig. 1 (2)). Consequently, the restore function ensures the sample gas can be easily re-measured even if a problem occurs during analysis.

However, it is difficult to simultaneously restore compounds with a wide range of low and high boiling points with the TD restore function because it is difficult to restore low boiling-point compounds while the sample tube is still hot immediately after desorption during sample gas restoring. Therefore, the sample tube will typically be replaced before

split sample gases enter the sample tube, but this increases the risk of gas leakage. If leakage occurs, it can cause both the analysis and restore process to fail. Using the original sample tube for restore provides an effective way to avoid such failures. That means that the sample tube must be cooled quickly before restoring low boiling-point compounds and also that the sample line temperature setting must be as low as possible. On the other hand, if the sample line temperature is too low, it could increase the likelihood of carryover for high boiling-point compounds.

To address these concerns, the TD-30R moves the sample tube away from the heat source while blow-cooling the sample tube during restoration process, enabling faster cooling than previously possible. In addition, taking into account the TD-30R sample line conditions (cooling and desorption temperature of the trap tube, desorption temperature and flow rate in the sample tube, temperature of the joint valve transfer line), we investigated the possibility of analyzing compounds with a wide range of boiling points with high sensitivity and a high restoration efficiency, and report on the results here.

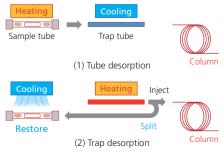


Fig. 1 TD Restore Function

2. Method

2-1. Measurement Sample Gas Preparation

Components from one to four liters of air from the atmosphere (the sample gas) were trapped by an adsorbent in a sample tube. It was analyzed within 30 days (stored at 4 °C max.) of trapping the sample gas components. 200 ng of Toluene-d8 (sealed in a gas cylinder with a concentration of 1 ppm, Capacity 3 L, Internal pressure 5 MPa, balance gas N₂) was added as an internal standard substance by an automated function. Sample gas components trapped in the trap tube were dry-purged with carrier gas before injection into the GC/MS system.

2-2. Analytical Conditions

A GCMS-QP[™]2020 single quadrupole mass spectrometer was used as the GC/MS system. The thermal desorption (TD) method with a TD-30R pretreatment unit was used for sample gas injection. Detailed analytical conditions are indicated in Table 1. Only the final optimized TD-30R analytical conditions are indicated.

Table 1 GC-MS Analytical Conditions

System Configuration GC/MS : GCMS-QP2020 Pretreatment Unit : TD-30R Software : GCMSsolution™ Ver.4.31, TD-30 Control Software Column : SH-624 (60 m x 0.32 mm I.D., df = 1.8 μm) (SHIMADZU, P/N: 221-75864-60) TD-30R

Sorbent Tube : TENAX**-TA / Carboxen® 1018 (Sigma-Aldrich, Cat No. 28718U)

Tube Desorption Temperature: 250 °C (10 min)
Tube Desorption Flowrate : 70 mL/min

Cold Trap : TENAX-TA / Carboxen 1000

 $(SHIMADZU, P/N: 223-54144-96) \\ Trap Cooling Temperature & : -25 \ ^{\circ}C$

Carrier Gas : Helium Control Mode : Pressure Pressure : 69 kPa

Injection Mode : Split 1: 10 (1.69 mL/min column flowrate) Column Oven Temperature : 35 °C (5 min) – (5 °C/min) – 230 °C (5 min)

MS

GC

Ion Source Temperature : 230 °C Interface Temperature : 200 °C

Measurement Mode : Scan/SIM Simultaneous Measurement

Scan Mass Range : m/z 20-600 Scan Event Time : 0.2 sec. Scan Speed : 3333 u/sec.

SIM Monitor Ion : Compliant with TO-17 regulation

3. Analysis Results

3-1. Study of Trap Tube Cooling Temperature

Due to the higher volatility of low boiling-point compounds, they are more likely than high boiling-point compounds to remain untrapped if the trap tube is not sufficiently cooled, resulting in poor analytical sensitivity. Therefore, the relationship between the trap tube cooling temperature and the sensitivity for analyzing low boiling-point compounds was considered at three trap tube cooling temperatures: 0, -20, and

-25 °C. Chromatograms for the compounds with particularly low boiling points detected in the given sample ((a) chloroethene and (b) ethyl chloride) are shown as examples in Fig. 2. Chloroethene (Fig. 2(a)) has a very low boiling point of -13 °C, but it can be detected with high sensitivity by decreasing the trap tube cooling temperature to -25 °C.

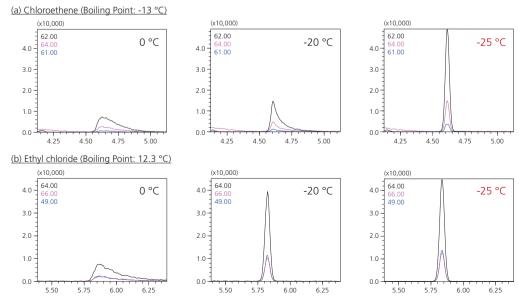


Fig. 2 Sensitivity Comparison for Low Boiling-Point Compounds Using Different Trap Tube Cooling Temperatures

3-2. Study of Trap Tube Desorption Temperature

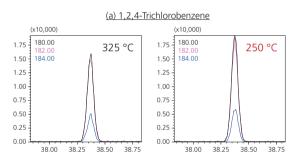
Considering cost and ease of maintenance, it is preferable to set the trap tube desorption temperature as low as possible. However, if the desorption temperature is too low, desorption of high boiling-point compounds will be more difficult, which can prevent their detection. Therefore, the relationship between the trap tube desorption temperature and the sensitivity for analyzing high boiling-point compounds was considered at two trap tube temperatures, 250 °C and

325 °C. Chromatograms for the compounds with particularly high boiling points detected in the given sample ((a) 1,2,4-trichlorobenzene and (b) o-dichlorobenzene) are shown in Fig. 3. Compound (a) 1,2,4-trichlorobenzene has a 213 °C boiling point, but can be detected with high sensitivity using a trap tube desorption temperature of 250 °C.

3-3. Study of Sample Tube Desorption Temperature

For thermal desorption, the sample tube and adsorbent can be reused as many times as desired by reconditioning the sample tube. However, if the sample tube thermal desorption process is insufficient, sample gas components can carry over from the previous measurement and affect the next measurement results. Consequently, we considered the sample tube desorption temperature and flowrate. Chromatograms for two compounds ((a) 1,2,4-trichlorobenzene and (b) hexachloro-1,3-butadiene) that carried over from among all the compounds detected in the given sample gas are shown in Fig. 4. The following two desorption temperature and flowrate conditions

were considered. Before optimization, the sample tube desorption temperature was 250 °C (5 min) and the tube desorption flowrate was 30 mL/min. After optimization, the sample tube desorption temperature was 250 °C (10 min) and the tube desorption flowrate was 70 mL/min. Given the conditions before optimization, the carryover value for (a) 1,2,4-trichlorobenzene was 5.4 %. In contrast, by specifying a longer thermal desorption time and a higher flowrate during desorption, as specified in the conditions after optimization, sufficient sample gas desorption occurred and the carryover value decreased to 0.7 %.



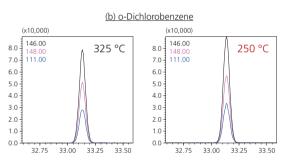


Fig. 3 Sensitivity Comparison for High Boiling-Point Compounds Using Different Trap Tube Desorption Temperatures

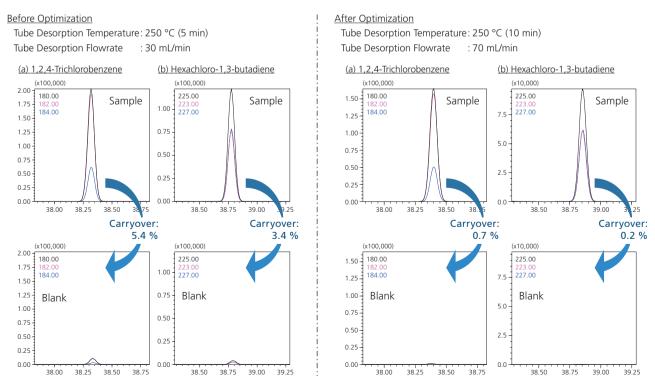


Fig. 4 Differences in Carryover Due to Different Desorption Temperatures and Flowrates in the Sample Tube

3-4. Study of Joint Temperature and Other Conditions

A low joint, valve, or transfer line temperature can cause cold spots in flow lines, whereas a high temperature can make it difficult to restore low boiling-point compounds in the sample tube. Therefore, it is important to specify joint, valve, and transfer line temperatures appropriately. The following presents an example of optimizing conditions that would enable restoring low boiling-point compounds. Before optimization, the joint temperature was 100 °C, the valve temperature was 200 °C, and the transfer line temperature was 250 °C. After optimization, the joint temperature was 75 °C, the valve temperature was 185 °C, and the transfer line temperature was 220 °C. As a

comparison of restoration efficiency for low boiling-point compounds before and after optimization, chromatograms for (a) chloroethene (boiling point: -13 °C), (b) ethyl chloride (boiling point: 12.3 °C), and (c) dichloromethane (boiling point: 39.6 °C) are shown in Fig. 5. Almost no low boiling-point components were detected during restoring before optimization, but lowering the temperature conditions for joints and other areas resulted in trapping the components in the sample tube and detecting them with adequate sensitivity after optimization.

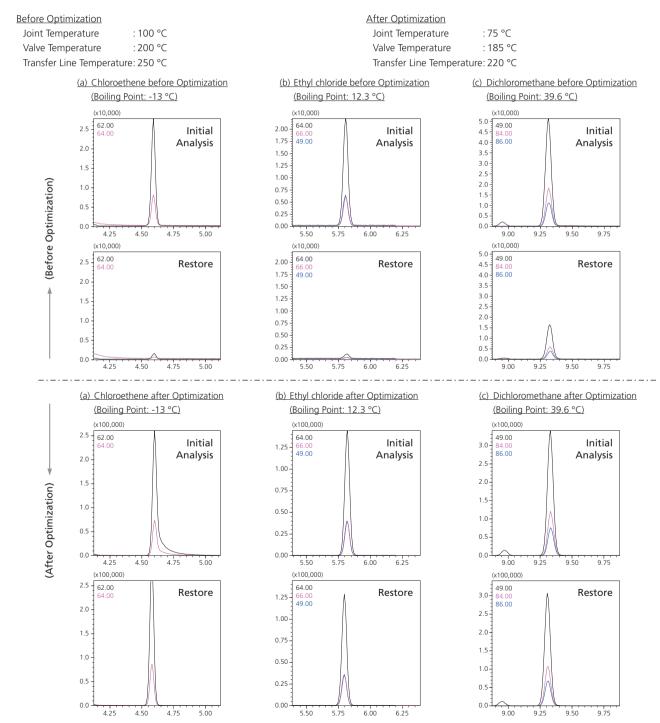


Fig. 5 Chromatograms of Three Low Boiling-Point Compounds from Initial Analysis of and after Restoring with Various Joint, Valve, and Transfer Line Temperatures

3-5. Reproducibility and Restoration Efficiency of Restore Function

Optimal analytical conditions were determined from the studies described above. Then the reproducibility and restoration efficiency for the restore function were determined for those conditions. First, a standard sample gas (mixture containing 1 µg each of 40 substances analyzed by the TO-17 method) was added to six sample tubes to determine whether or not adequate measurement reproducibility was achieved based on initial analysis and restore results. Those measurement results are shown in Table 2. Mean values from measuring the six sample tubes were used as the standard sample quantitation values. Quantitation values were calculated from the calibration curve prepared in accordance with TO-17 based on the peak area ratio for each concentration ob-

tained from adding 1 to 50 μ g of the standard sample. Table 3 shows the linearity of the calibration curve. Table 2 shows that the relative standard deviation (%RSD) is within 10 % for all substances and the %RSD value was about the same for both the initial analysis and restoring for most substances, which indicates good analytical reproducibility even when using the restore function. The difference between the %RSD value for the initial analysis and restore was large only for ethyl chloride (I.D. No. 5 in Table 2). That large difference was presumably caused by the larger difference in recovery rates between ethyl chloride and toluene-d8, used as an internal standard substance during restoring, than for other substances.

Table 2 Reproducibility for 1 µg Standard Sample Gas

Table 3 Calibration Curve Linearity
(1 to 50 μg Standard Sample Gas Added)

1		Table 2 Repro-	ducibility for 1 p		(1 to 50 µg Standard Sample Gas Added)					
Initial Analysis Restore Initial Analysis Initial Analysis Restore Initial Analysis Initial Analysis Restore Initial Analysis Initial Ini	ID	Component	Quantitation \	/alues (µg)	%RSD (n=6)			Composit	Linearity	
2 Chloroethene 1.01 1.00 4.81 4.57 2 Chloroethene 0.9999 0.9993 3 1.3.8utadiene 1.03 1.03 4.90 3.95 3 1.3.8utadiene 0.9962 0.9955 0.9965 0.9965 0.9955 0.9965 0.9965 0.9955 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9965 0.9966 0.9966 0.9968 0.9996 0.998 0.9991 <td< th=""><th>I.D.</th><th>Initial Analysis</th><th>Restore</th><th>Initial Analysis</th><th>Restore</th><th>1.0.</th><th>Component</th><th>Initial Analysis</th><th>Restore</th></td<>	I.D.		Initial Analysis	Restore	Initial Analysis	Restore	1.0.	Component	Initial Analysis	Restore
3 1,3-8utadiene	1	Freon 114	1.04	1.03	3.55	4.04	1	Freon 114	0.9991	0.9993
4 Methyl bromide 0.94 0.99 3.56 4.88 4 Methyl bromide 0.9962 0.9952 5 Ethyl chloride 1.04 1.09 3.69 9.18 5 Ethyl chloride 0.9986 0.9997 7 1.1-Dichloroethene 1.03 1.03 3.41 3.80 6 Freon 113 0.9992 0.9993 9 3-Chloro-1-propene 0.998 0.999 4.34 3.94 9 3-Chloro-1-propene 0.9999 1.09991 0.9991 10 Methylene chloride 1.04 1.02 3.32 3.84 10 Methylene chloride 0.999 0.9093 11 Acrylonitrile 0.96 0.93 5.03 5.10 11 Acrylonitrile 0.999 0.9993 12 1.1-Dichloroethane 1.02 1.01 2.88 3.78 13 dis-Di-1,2-Dichloroethane 0.9991 0.9991 13 dis-Di-1,2-Dichloroethylene 1.02 1.01 2.83 3.78 13	2	Chloroethene	1.01	1.00	4.81	4.57	2	Chloroethene	0.9999	0.9997
5 Ethyl chloride 1.04 1.09 3.69 9.18 5 Ethyl chloride 0.9986 0.9986 6 Freon 11 1.03 1.04 3.41 3.80 6 Freen 11 0.9994 0.998 8 Freon 113 1.02 1.03 3.03 3.75 8 Freon 113 0.9992 0.9991 9 3.Chloro-1-propene 0.98 0.99 4.34 3.94 9 3.Chloro-1-propene 0.9991 1.090 10 Methylene chloride 1.04 1.02 3.10 3.77 1.0 Methylene chloride 0.9991 0.9991 11 Acrylonitrile 0.96 0.93 5.03 5.10 11 Acrylonitrile 0.9991 0.9991 12 1,1-Dichloroethane 1.03 1.02 3.10 3.77 12 1,1-Dichloroethane 0.9991 0.9991 13 cis-Di-1,2-Dichloroethylene 0.9991 0.9991 0.9991 0.9991 15 1,1-Trichloroethane	3	1,3-Butadiene	1.03	1.03	4.90	3.95	3	1,3-Butadiene	0.9995	0.9987
6 Freon 11 1.03 1.04 3.41 3.80 6 Freon 11 0.9994 0.9995 7 1,1-Dichloroethene 1.03 1.03 3.39 3.71 7 1,1-Dichloroethene 0.9991 0.9991 9 3-Chloro-1-propene 0.98 0.99 4.34 3.94 9 3-Chloro-1-propene 0.9999 1.000 10 Methylene chloride 1.04 1.02 3.32 3.84 10 Methylene chloride 0.9990 0.9991 0.9991 11 Acrylonitrile 0.96 0.93 5.03 5.10 11 Acrylonitrile 0.9991 0.9991 12 1,1-Dichloroethane 1.03 1.02 3.10 3.77 11 Acrylonitrile 0.9995 0.9995 13 cis-Di-1,2-Dichloroethylene 1.02 1.01 2.88 3.78 13 cis-Di-1,2-Dichloroethylene 0.9995 0.9995 14 Chloroform 1.04 1.07 4.64 6.45 14 <t< th=""><th>4</th><th>Methyl bromide</th><th>0.94</th><th>0.99</th><th>3.56</th><th>4.88</th><th>4</th><th>Methyl bromide</th><th>0.9962</th><th>0.9957</th></t<>	4	Methyl bromide	0.94	0.99	3.56	4.88	4	Methyl bromide	0.9962	0.9957
7 1,1-Dichloroethene 1.03 1.03 3.39 3.71 8 Freon 113 1.02 1.03 3.03 3.75 9 3-Chloro-1-propene 0.98 0.99 4.34 3.94 10 Methylene chloride 1.04 1.02 3.32 3.84 11 Acrylonitrile 0.96 0.93 5.03 5.10 11 Acrylonitrile 0.96 0.93 5.03 5.10 12 1,1-Dichloroethane 1.03 1.02 3.10 3.77 13 cis-D-1,2-Dichloroethylene 1.02 1.01 2.88 3.78 14 Chloroform 1.04 1.07 4.64 6.45 15 1,1,1-Tichloroethane 1.03 1.04 2.285 3.50 16 Carbon tetrachloride 1.03 1.03 3.00 4.16 17 Benzene 1.05 1.04 2.32 2.68 18 1,2-Dichloroethylene 0.999 0.999	5	Ethyl chloride	1.04	1.09	3.69	9.18	5	Ethyl chloride	0.9986	0.9996
8 Freon 113 1.02 1.03 3.03 3.75 9 3-Chloro-1-propene 0.98 0.99 4.34 3.94 10 Methylene chloride 1.04 1.02 3.32 3.84 11 Acrylonitrile 0.96 0.93 5.03 5.10 12 1,1-Dichloroethane 1.03 1.02 3.10 3.77 13 cis-Di-1,2-Dichloroethylene 1.02 1.01 2.88 3.78 14 Chloroform 1.04 1.07 4.64 6.45 14 Chloroform 1.04 1.07 4.64 6.45 15 1,1,1-Trichloroethane 1.03 1.03 3.00 4.16 16 Carbon tetrachloride 1.03 1.03 3.00 4.16 18 1,2-Dichloroethane 1.05 1.04 2.32 2.68 19 Trichloroethylene 0.86 0.75 3.35 6.26 21 1,3-Dichloropropane 1.02 1.02 <th>6</th> <th>Freon 11</th> <th>1.03</th> <th>1.04</th> <th>3.41</th> <th>3.80</th> <th>6</th> <th>Freon 11</th> <th>0.9994</th> <th>0.9995</th>	6	Freon 11	1.03	1.04	3.41	3.80	6	Freon 11	0.9994	0.9995
9 3-Chloro-1-propene 0.98 0.99 4.34 3.94 10 Methylene chloride 1.04 1.02 3.32 3.84 10 Methylene chloride 0.9990 0.9990 0.9991 1.000 11 Acrylonitrile 0.96 0.93 5.03 5.10 11 Acrylonitrile 0.9991 </th <th>7</th> <th>1,1-Dichloroethene</th> <th>1.03</th> <th>1.03</th> <th>3.39</th> <th>3.71</th> <th>7</th> <th>1,1-Dichloroethene</th> <th>0.9991</th> <th>0.9991</th>	7	1,1-Dichloroethene	1.03	1.03	3.39	3.71	7	1,1-Dichloroethene	0.9991	0.9991
10 Methylene chloride	8	Freon 113	1.02	1.03	3.03	3.75	8	Freon 113	0.9992	0.9993
11	9	3-Chloro-1-propene	0.98	0.99	4.34	3.94	9	3-Chloro-1-propene	0.9999	1.0000
12	10	Methylene chloride	1.04	1.02	3.32	3.84	10	Methylene chloride	0.9990	0.9995
13 dis-Di-1,2-Dichloroethylene 1.02 1.01 2.88 3.78 13 dis-Di-1,2-Dichloroethylene 0.9995 0.9995 0.9995 15 1,1-Trichloroethane 1.03 1.04 2.85 3.50 15 1,1-Trichloroethane 1.03 1.04 2.85 3.50 15 1,1-Trichloroethane 0.9997 0.9998 16 Carbon tetrachloride 1.03 1.03 3.00 4.16 16 Carbon tetrachloride 0.9997 0.9998 17 Benzene 1.05 1.04 2.32 2.68 17 Benzene 0.9999 0.9999 18 1,2-Dichloroethane 1.02 1.01 2.76 2.37 18 1,2-Dichloroethylene 0.9995 0.9998 0.9999 19 Trichloroethylene 0.86 0.75 3.45 6.26 19 Trichloroethylene 0.9998 0.9998 0.9999 1.2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloropropane 0.995 0.999 0.9995 0	11	Acrylonitrile	0.96	0.93	5.03	5.10	11	Acrylonitrile	0.9991	0.9981
14 Chloroform 1.04 1.07 4.64 6.45 14 Chloroform 0.9997 0.9995 15 1,1,1-Trichloroethane 1.03 1.04 2.85 3.50 15 1,1,1-Trichloroethane 0.9997 0.9998 16 Carbon tetrachloride 1.03 1.03 3.00 4.16 16 Carbon tetrachloride 0.9997 0.9998 17 Benzene 1.05 1.04 2.32 2.68 17 Benzene 0.9999 0.9999 18 1,2-Dichloroethane 1.02 1.01 2.76 2.37 18 1,2-Dichloroethane 0.9999 0.9999 19 Trichloroethylene 0.86 0.75 3.45 6.26 19 Trichloroethylene 0.9999 0.9999 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloropropane 0.9999 0.9999 21 1,3-Dichloropropane 0.95 0.90 0.80 9.87 21 1,3-Dichloropropa	12	1,1-Dichloroethane	1.03	1.02	3.10	3.77	12	1,1-Dichloroethane	0.9995	0.9995
15 1,1,1-Trichloroethane 1.03 1.04 2.85 3.50 15 1,1,1-Trichloroethane 0.9997 0.9998 16 Carbon tetrachloride 1.03 1.03 3.00 4.16 16 Carbon tetrachloride 0.9997 0.9998 17 Benzene 1.05 1.04 2.32 2.68 17 Benzene 0.9999 0.9999 18 1,2-Dichloroethane 1.02 1.01 2.76 2.37 18 1,2-Dichloroethylene 0.9999 0.9999 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloroptopene 0.9998 0.9998 21 1,3-Dichloropropane 0.95 0.90 9.60 9.87 21 1,3-Dichloropropane 0.9999 0.9999 22 Toluene 0.96 0.89 1.80 2.80 22 Toluene 0.9999 0.9999 23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 23 1,1,2-Trichloro	13	cis-Di-1,2-Dichloroethylene	1.02	1.01	2.88	3.78	13	cis-Di-1,2-Dichloroethylene	0.9995	0.9995
16 Carbon tetrachloride 1.03 1.03 3.00 4.16 17 Benzene 1.05 1.04 2.32 2.68 18 1.2-Dichloroethane 1.02 1.01 2.76 2.37 19 Trichloroethylene 0.86 0.75 3.45 6.26 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 21 1,3-Dichloropropane 0.95 0.90 9.60 9.87 22 Toluene 0.96 0.89 1.80 2.80 23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 24 Tetrachloroethylene 0.99 0.84 2.19 2.96 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 26 Chlorobenzene 1.01 1.02 1.20 1.86 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 1.01 1.01 1.04 <th>14</th> <th>Chloroform</th> <th>1.04</th> <th>1.07</th> <th>4.64</th> <th>6.45</th> <th>14</th> <th>Chloroform</th> <th>0.9997</th> <th>0.9999</th>	14	Chloroform	1.04	1.07	4.64	6.45	14	Chloroform	0.9997	0.9999
17 Benzene 1.05 1.04 2.32 2.68 17 Benzene 0.9999 0.9999 18 1,2-Dichloroethane 1.02 1.01 2.76 2.37 18 1,2-Dichloroethane 0.9995 0.9995 19 Trichloroethylene 0.86 0.75 3.45 6.26 19 Trichloroethylene 0.9998 0.9995 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 21 1,3-Dichloropropane 0.999 0.9998 22 Toluene 0.96 0.89 1.80 2.80 23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 23 1,12-Trichloroethane 0.9999 0.9999 24 Tetrachloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9999 0.9998 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 25 1,2-Dibromoethane 0.9999 0.9999 2	15	1,1,1-Trichloroethane	1.03	1.04	2.85	3.50	15	1,1,1-Trichloroethane	0.9997	0.9998
18 1,2-Dichloroethane 1.02 1.01 2.76 2.37 18 1,2-Dichloroethane 0.9995 0.9995 19 Trichloroethylene 0.86 0.75 3.45 6.26 19 Trichloroethylene 0.9998 0.9998 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloropropane 0.9996 0.9999 21 1,3-Dichloropropene 0.95 0.90 9.60 9.87 21 1,3-Dichloropropene 0.9999 0.9996 22 Toluene 0.96 0.89 1.80 2.80 22 Toluene 0.9999 0.9999 23 1,1,2-Trichloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9999 0.9999 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 25 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.01 1.02 1.20 1.86 28 m-Xylene <th>16</th> <th>Carbon tetrachloride</th> <th>1.03</th> <th>1.03</th> <th>3.00</th> <th>4.16</th> <th>16</th> <th>Carbon tetrachloride</th> <th>0.9997</th> <th>0.9998</th>	16	Carbon tetrachloride	1.03	1.03	3.00	4.16	16	Carbon tetrachloride	0.9997	0.9998
19 Trichloroethylene 0.86 0.75 3.45 6.26 19 Trichloroethylene 0.9998 0.9998 20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloropropane 0.9996 0.9996 21 1,3-Dichloropropene 0.95 0.90 9.60 9.87 21 1,3-Dichloropropene 0.9999 0.9997 22 Toluene 0.96 0.89 1.80 2.80 22 Toluene 0.9999 0.9999 0.9999 24 Tetrachloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9999 0.9999 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 2 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.03 1.03 1.48 2.20 27 Ethylbenzene 1.00 0.9998 0.9998 0.9998 28 m-Xylene 1.01 1.02 1.20 1.86	17	Benzene	1.05	1.04	2.32	2.68	17	Benzene	0.9999	0.9999
20 1,2-Dichloropropane 1.02 1.02 2.09 2.39 20 1,2-Dichloropropane 0.9996 0.9996 21 1,3-Dichloropropene 0.95 0.90 9.60 9.87 21 1,3-Dichloropropene 0.9999 0.9999 22 Toluene 0.96 0.89 1.80 2.80 22 Toluene 0.9999 0.9999 23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 23 1,1,2-Trichloroethane 0.9999 0.9999 24 Tetrachloroethylene 0.999 0.9998 0.9998 0.9999 25 1,2-Dibromoethane 1.01 1.01 1.06 0.54 25 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.01 0.999 1.73 2.09 26 Chlorobenzene 1.0000 0.9993 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9999 29 p-Xyle	18	1,2-Dichloroethane	1.02	1.01	2.76	2.37	18	1,2-Dichloroethane	0.9995	0.9995
21 1,3-Dichloropropene 0.95 0.90 9.60 9.87 22 Toluene 0.96 0.89 1.80 2.80 23 1,1,2-Trichloroethane 1.02 1.57 1.15 2.15 24 Tetrachloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9999 0.9999 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 25 1,2-Dibromoethane 0.9999 0.9998 26 Chlorobenzene 1.01 0.99 1.73 2.09 26 Chlorobenzene 1.000 0.9998 0.9998 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 31 Styrene 1.01 1.01 1.04 0.51 31 Styrene 0.9998 0.9993	19	Trichloroethylene	0.86	0.75	3.45	6.26	19	Trichloroethylene	0.9998	0.9999
22 Toluene 0.96 0.89 1.80 2.80 23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 24 Tetrachloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9999 0.9999 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 25 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.01 0.99 1.73 2.09 26 Chlorobenzene 1.0000 0.9998 27 Ethylbenzene 1.03 1.03 1.48 2.20 27 Ethylbenzene 0.9999 0.9998 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 o-Xylene 1.02 1.02 1.04 0.51 31 Styrene <th>20</th> <th>1,2-Dichloropropane</th> <th>1.02</th> <th>1.02</th> <th>2.09</th> <th>2.39</th> <th>20</th> <th>1,2-Dichloropropane</th> <th>0.9996</th> <th>0.9996</th>	20	1,2-Dichloropropane	1.02	1.02	2.09	2.39	20	1,2-Dichloropropane	0.9996	0.9996
23 1,1,2-Trichloroethane 1.02 1.02 1.57 1.15 23 1,1,2-Trichloroethane 0.9999 0.9999 0.9999 24 Tetrachloroethylene 0.90 0.84 2.19 2.96 24 Tetrachloroethylene 0.9995 0.9996 25 1,2-Dibromoethane 1.01 1.01 1.66 0.54 25 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.01 0.99 1.73 2.09 26 Chlorobenzene 1.0000 0.9998 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 o-Xylene 1.02 1.02 1.34 1.60 30 o-Xylene 0.9998 0.9998 31 Styrene 1.01 1.01 1.04 0.51 31 Styrene 0.9998	21	1,3-Dichloropropene	0.95	0.90	9.60	9.87	21	1,3-Dichloropropene	0.9999	0.9997
24 Tetrachloroethylene 0.90 0.84 2.19 2.96 25 1,2-Dibromoethane 1.01 1.06 0.54 26 Chlorobenzene 1.01 0.99 1.73 2.09 27 Ethylbenzene 1.03 1.03 1.48 2.20 28 m-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 0-Xylene 1.02 1.02 1.34 1.60 30 0-Xylene 1.01 1.01 1.04 0.51 31 Styrene 0.9998 0.9997 31 Styrene 1.01 1.01 0.40 0.51 31 Styrene 0.9998 0.9998 32 1,1,2,2-Tetrachloroethane 0.995 0.92 1.71 1.90 32 1,1,2,2-Tetrachl	22	Toluene	0.96	0.89	1.80	2.80	22	Toluene	0.9999	0.9998
25 1,2-Dibromoethane 1.01 1.06 0.54 25 1,2-Dibromoethane 0.9998 0.9998 26 Chlorobenzene 1.01 0.99 1.73 2.09 26 Chlorobenzene 1.0000 0.9998 27 Ethylbenzene 1.03 1.03 1.48 2.20 27 Ethylbenzene 0.9999 0.9999 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 0-Xylene 1.02 1.02 1.34 1.60 30 0-Xylene 0.9998 0.9998 31 Styrene 1.01 1.01 1.04 0.51 31 Styrene 0.9998 0.9997 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 32 1,1,2,2-Tetrachloroethane 0.9999 0.9993 3	23	1,1,2-Trichloroethane	1.02	1.02	1.57	1.15	23	1,1,2-Trichloroethane	0.9999	0.9999
26 Chlorobenzene 1.01 0.99 1.73 2.09 27 Ethylbenzene 1.03 1.03 1.48 2.20 28 m-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 1.01 1.02 1.20 1.86 30 o-Xylene 1.02 1.02 1.34 1.60 31 Styrene 1.01 1.01 1.04 0.51 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.995 0.992 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.50 0.51 <t< th=""><th>24</th><th>Tetrachloroethylene</th><th>0.90</th><th>0.84</th><th>2.19</th><th>2.96</th><th>24</th><th>Tetrachloroethylene</th><th>0.9995</th><th>0.9996</th></t<>	24	Tetrachloroethylene	0.90	0.84	2.19	2.96	24	Tetrachloroethylene	0.9995	0.9996
27 Ethylbenzene 1.03 1.03 1.48 2.20 28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 o-Xylene 1.02 1.02 1.34 1.60 30 o-Xylene 0.9998 0.9998 31 Styrene 1.01 1.01 1.04 0.51 31 Styrene 0.9998 0.9997 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 32 1,1,2,2-Tetrachloroethane 0.9994 0.9993 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 33 1,3,5-Trimethylbenzene 0.9995 0.9992 34 1,2,4-Trimethylbenzene 1.02 1.03 3.41 3.74 34 1,2,4-Trimethylbenzene 0.9995 0.9992 36 m-Dichlorobenzene	25	1,2-Dibromoethane	1.01	1.01	1.66	0.54	25	1,2-Dibromoethane	0.9998	0.9999
28 m-Xylene 1.01 1.02 1.20 1.86 28 m-Xylene 0.9998 0.9998 0.9998 29 p-Xylene 1.01 1.02 1.20 1.86 29 p-Xylene 0.9998 0.9998 30 o-Xylene 1.02 1.02 1.34 1.60 30 o-Xylene 0.9998 0.9998 31 Styrene 1.01 1.01 1.04 0.51 31 Styrene 0.9998 0.9998 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 32 1,1,2,2-Tetrachloroethane 0.9994 0.9993 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 33 1,3,5-Trimethylbenzene 0.9995 0.9992 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 34 1,2,4-Trimethylbenzene 0.9994 0.9992 35 4-Ethyltoluene 0.9995 0.9993 35 4-Ethyltoluene 0.9995 0.9993	26	Chlorobenzene	1.01	0.99	1.73	2.09	26	Chlorobenzene	1.0000	0.9999
29 p-Xylene 1.01 1.02 1.20 1.86 30 o-Xylene 1.02 1.02 1.34 1.60 31 Styrene 1.01 1.01 1.04 0.51 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 39 1,2,4-Trichlorobenzene 0.9993 0.9993	27	Ethylbenzene	1.03	1.03	1.48	2.20	27	Ethylbenzene	0.9999	0.9999
30 o-Xylene 1.02 1.02 1.34 1.60 31 Styrene 1.01 1.01 1.04 0.51 32 1,1,2,2-Tetrachloroethane 0.995 0.92 1.71 1.90 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 39 1,2,4-Trichlorobenzene 0.9993 0.9993 39 1,2,4-Trichlorobenzene 0.9993 0.9993	28	m-Xylene	1.01	1.02	1.20	1.86	28	m-Xylene	0.9998	0.9998
31 Styrene 1.01 1.04 0.51 32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 39 1,2,4-Trichlorobenzene 0.9993 0.9993 39 1,2,4-Trichlorobenzene 0.9993 0.9993	29	p-Xylene	1.01	1.02	1.20	1.86	29	p-Xylene	0.9998	0.9998
32 1,1,2,2-Tetrachloroethane 0.95 0.92 1.71 1.90 33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 39 1,2,4-Trichlorobenzene 0.9993 0.9993 39 1,2,4-Trichlorobenzene 0.9993 0.9993 39 1,2,4-Trichlorobenzene 0.9993 0.9993	30	o-Xylene	1.02	1.02	1.34	1.60	30	o-Xylene	0.9998	0.9997
33 1,3,5-Trimethylbenzene 1.01 1.01 0.80 1.20 34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 37 p-Dichlorobenzene 0.9995 0.9995 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9993 39 1,2,4-Trichlorobenzene 0.85 0.82 7.55 6.30 39 1,2,4-Trichlorobenzene 0.9993 0.9988	31	Styrene	1.01	1.01	1.04	0.51	31	Styrene	0.9998	0.9997
34 1,2,4-Trimethylbenzene 1.02 1.03 1.02 1.37 34 1,2,4-Trimethylbenzene 0.9994 0.9992 35 4-Ethyltoluene 0.97 1.03 3.41 3.74 35 4-Ethyltoluene 0.9995 0.9992 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 36 m-Dichlorobenzene 0.9995 0.9993 37 p-Dichlorobenzene 0.999 1.01 1.52 0.63 37 p-Dichlorobenzene 0.9995 0.9993 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9992 39 1,2,4-Trichlorobenzene 0.9993 0.9983	32	1,1,2,2-Tetrachloroethane	0.95	0.92	1.71	1.90	32	1,1,2,2-Tetrachloroethane	0.9994	0.9993
35 4-Ethyltoluene 0.97 1.03 3.41 3.74 35 4-Ethyltoluene 0.9995 0.9992 36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 36 m-Dichlorobenzene 0.9995 0.9993 37 p-Dichlorobenzene 0.999 1.01 1.52 0.63 37 p-Dichlorobenzene 0.9995 0.9993 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9992 39 1,2,4-Trichlorobenzene 0.9993 0.9988	33	1,3,5-Trimethylbenzene	1.01	1.01	0.80	1.20	33	1,3,5-Trimethylbenzene	0.9995	0.9994
36 m-Dichlorobenzene 1.00 1.01 1.50 0.51 36 m-Dichlorobenzene 0.9995 0.9995 0.9995 37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 37 p-Dichlorobenzene 0.9995 0.9995 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9992 39 1,2,4-Trichlorobenzene 0.9993 0.9988	34	1,2,4-Trimethylbenzene	1.02	1.03	1.02	1.37	34	1,2,4-Trimethylbenzene	0.9994	0.9992
37 p-Dichlorobenzene 0.99 1.01 1.52 0.63 37 p-Dichlorobenzene 0.9995 0.9995 38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9992 39 1,2,4-Trichlorobenzene 0.85 0.82 7.55 6.30 39 1,2,4-Trichlorobenzene 0.9993 0.9988	35	4-Ethyltoluene	0.97	1.03	3.41	3.74	35	4-Ethyltoluene	0.9995	0.9992
38 o-Dichlorobenzene 1.00 1.01 2.07 0.40 38 o-Dichlorobenzene 0.9992 0.9992 39 1,2,4-Trichlorobenzene 0.85 0.82 7.55 6.30 39 1,2,4-Trichlorobenzene 0.9993 0.9988	36	m-Dichlorobenzene	1.00	1.01	1.50	0.51	36	m-Dichlorobenzene	0.9995	0.9993
39 1,2,4-Trichlorobenzene 0.85 0.82 7.55 6.30 39 1,2,4-Trichlorobenzene 0.9993 0.9988	37	p-Dichlorobenzene	0.99	1.01	1.52	0.63	37	p-Dichlorobenzene	0.9995	0.9993
	38	o-Dichlorobenzene	1.00	1.01	2.07	0.40	38	o-Dichlorobenzene	0.9992	0.9990
40 Hexachloro-1,3-butadiene 1.03 1.00 4.97 4.17 40 Hexachloro-1,3-butadiene 0.9983 0.9983	39	1,2,4-Trichlorobenzene	0.85	0.82	7.55	6.30	39	1,2,4-Trichlorobenzene	0.9993	0.9988
	40	Hexachloro-1,3-butadiene	1.03	1.00	4.97	4.17	40	Hexachloro-1,3-butadiene	0.9983	0.9983

Quantitation results for an actual sample gas are shown in Table 4. For the actual sample gas, air was sampled from two different locations within a room. Results marked "N.D." in the table indicate that none of the substance was detected in the actual sample gas using the given analytical equipment, whereas "<LOQ" indicates that the measured value was less than the lower limit of quantitation. In this case, the lower limit of quantitation is ten times the standard deviation value σ calculated from measurement values in Table 2. Table 4 shows that for each component detected in the actual sample gas at a concentration higher than the lower limit of quantitation, the quantitated values from the initial analysis are about the same as from restoring, which indicates that quantitation values have good reproducibility.

Furthermore, the measurement values for each component detected in the measurement sample gas at a concentration higher than the lower limit of quantitation tend to be larger when restoring than from the initial analysis. That tendency was presumably due to the lower recovery rates of toluene-d8, used as an internal standard substance during restoring, than for other substances.

The above results show that the TD-30R restore function can be used to analyze samples that contain VOCs with a wide range of low to high boiling points with accuracy that is comparable to the initial analysis. The restore function not only can be used to hedge against risks when analyzing precious samples, but also enables high-sensitivity analysis with high restoration efficiency.

Table 4 Quantitation Results for Actual Sample Gas

I.D.	Component	Д	Actual Sample Gas	; 1	Actual Sample Gas 2			
		Initial Analysis	Restore	Ratio (Restore/Initial)	Initial Analysis	Restore	Ratio (Restore/Initial)	
1	Freon 114	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
2	Chloroethene	N.D.	N.D.	-	N.D.	N.D.	-	
3	1,3-Butadiene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
4	Methyl bromide	N.D.	N.D.	-	N.D.	N.D.	-	
5	Ethyl chloride	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
6	Freon 11	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
7	1,1-Dichloroethene	N.D.	N.D.	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
8	Freon 113	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
9	3-Chloro-1-propene	N.D.	N.D.	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
10	Methylene chloride	0.69	0.77	1.12	1.23	1.37	1.11	
11	Acrylonitrile	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
12	1,1-Dichloroethane	N.D.	N.D.	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
13	cis-Di-1,2-Dichloroethylene	N.D.	N.D.	-	N.D.	N.D.	-	
14	Chloroform	<loq< td=""><td><loq< td=""><td>-</td><td>13.5</td><td>13.7</td><td>1.01</td></loq<></td></loq<>	<loq< td=""><td>-</td><td>13.5</td><td>13.7</td><td>1.01</td></loq<>	-	13.5	13.7	1.01	
15	1,1,1-Trichloroethane	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
16	Carbon tetrachloride	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
17	Benzene	0.32	0.34	1.06	0.53	0.55	1.04	
18	1,2-Dichloroethane	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
19	Trichloroethylene	0.4	<loq< td=""><td>-</td><td>0.39</td><td><loq< td=""><td>-</td></loq<></td></loq<>	-	0.39	<loq< td=""><td>-</td></loq<>	-	
20	1,2-Dichloropropane	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
21	1,3-Dichloropropene	N.D.	N.D.	-	N.D.	N.D.	-	
22	Toluene	3.08	3.26	1.06	3.95	4.06	1.03	
23	1,1,2-Trichloroethane	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
24	Tetrachloroethylene	0.2	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
25	1,2-Dibromoethane	N.D.	N.D.	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
26	Chlorobenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
27	Ethylbenzene	0.42	0.43	1.02	0.18	<loq< td=""><td>-</td></loq<>	-	
28	m-Xylene	0.20	0.21	1.05	0.3	0.3	1.00	
29	p-Xylene	0.20	0.21	1.05	0.3	0.3	1.00	
30	o-Xylene	0.14	0.15	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
31	Styrene	0.12	0.13	1.08	<loq< td=""><td>0.08</td><td>-</td></loq<>	0.08	-	
32	1,1,2,2-Tetrachloroethane	N.D.	N.D.	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
33	1,3,5-Trimethylbenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
34	1,2,4-Trimethylbenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
35	4-Ethyltoluene	2.41	2.81	1.17	1.82	2.04	1.12	
36	m-Dichlorobenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
37	p-Dichlorobenzene	<loq< td=""><td>0.09</td><td>-</td><td><loq< td=""><td>0.09</td><td>-</td></loq<></td></loq<>	0.09	-	<loq< td=""><td>0.09</td><td>-</td></loq<>	0.09	-	
38	o-Dichlorobenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
39	1,2,4-Trichlorobenzene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	
40	Hexachloro-1,3-butadiene	<loq< td=""><td><loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<></td></loq<>	<loq< td=""><td>-</td><td><loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<></td></loq<>	-	<loq< td=""><td><loq< td=""><td>-</td></loq<></td></loq<>	<loq< td=""><td>-</td></loq<>	-	

4. Conclusions

The authors developed a TD system (TD-30R) capable of simultaneous analysis of compounds with a wide range of boiling points and with high sensitivity and high restoration efficiency. As a result of using the optimized analytical conditions determined by experimentally considering the trap tube cooling and desorption temperature, the sample tube desorption temperature and flowrate, and the joint, valve, and transfer line temperatures, VOCs with a wide range of

boiling points were analyzed using the restore function with accuracy levels equivalent to initial analysis.

Consequently, using the TD-30R unit not only can help avoid the risk of wasting precious VOC samples, but also enables simultaneous analysis of compounds with a wide range of boiling points, while also achieving high sensitivity and high restoration efficiency.

TD-30R Thermal Desorption System

Revolutionary Thermal Desorption System Provides Excellent Processing Ability and Reliability

The TD-30 was developed as the optimal solution for gas and materials analysis. Its outstanding processing ability and excellent expandability provide strong support for all types of analysis, from work in research departments to quality control.

Outstanding Processing Ability and Basic Functionality

- ► Extensive sample capacity capable of accommodating 120 samples
- ▶ Efficient analysis with the overlap function and interrupt function
- ▶ High-sensitivity analysis of high boiling point components using a sample line with no cold points

Excellent Expandability Enables a Variety of Analyses

- ► Hedging risks with the restore function
- ▶ Highly accurate quantitative analysis using a function that automatically adds an internal standard
- ▶ Highly reliable sample management using a barcode reader

Simple Operations and Ease of Maintenance

- ► Easy-to-maintain, user-friendly design
- ► Simple, easy-to-operate software



TD-30R

Specifications and Installation Conditions

Tube Desorption Temperature Settings: 0 °C to 430 °C (1 °C increments), Control: Room temperature +15 °C to 430 °C (Accuracy ±1 °C) Tube Desorption Flow Rate Settings: 20 mL/min to 200 mL/min (1 mL/min increments; Accuracy ±2 mL/min) Tube Desorption Time Settings: 0 min to 240 min (0.01 min increments) Trap Size Outer diameter: 176" (3.2 mm); Inner diameter: 2 mm; Length: 102 mm SilcoNert* 2000 stainless steel tube rendered inert Trap Adsorbent TENAX-Ta 60-80 mesh (60 mg) is standard. Carboxaen 1000 (70 mg) is optionally available. Carboxaen 1000 (70 mg) is optionally available. Trap Desorption Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1 °C) Trap Cooling Temperature Settings: -40 °C to 80 °C (1 °C increments); Control: Room temperature -45 °C to 80 °C (Valve temperature < 250 °C); (Accuracy ±1 °C) Split Ratio 1:5 to 1:200 Sample Path SilcoNert 2000 Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge	Tube Size	Outer diameter: 1/4" (6.35 mm); Length: 3.5" (89 mm)			
Tube Description Time Settings: 0 min to 240 min (0.01 min increments) Trap Size Outer diameter: 1/8" (3.2 mm); Inner diameter: 2 mm; tength: 102 mm SilcoNert® 2000 stainless steel tube rendered inert Trap Adsorbent Trap Adsorbent Trap Adsorbent Trap Adsorbent Trap Description Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1°C) Settings: -40 °C to 80 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1°C) Settings: -40 °C to 80 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1°C) Split Ratio 1: 5 to 1:200 Sample Path SilcoNert 2000 Switching Valve Gettings: 0 °C to 300 °C (1 °C increments); Control: Room temperature -45 °C to 80 °C (Valve temperature >250 °C); (Accuracy ±1 °C) Switching Valve Gettings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) T	Tube Desorption Temperature				
Trap Size Outer diameter: 1/8" (3.2 mm); Inner diameter: 2 mm; Length: 102 mm SilcoNert® 2000 stainless steel tube rendered inert Trap Adsorbent TRAX-TA 60-80 mesh (60 mg) is standard. Carbopack® (50 mg) + Carbosieve® (10 mg) are optionally available. Carboxen 1000 (70 mg) is optionally available. Trap Desorption Temperature Settings: 0°C to 350 °C (1°C increments); Control: 0°C to 350 °C (Accuracy ±1°C) Settings: -40 °C to 80 °C (1°C increments); Control: 0°C to 350 °C, (Rocuracy ±1°C) Spirt Ratio 1:5 to 1:200 Sample Path SilcoNert 2000 Switching Valve 6:port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0°C to 300 °C (1°C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1°C) Valve Temperature Settings: 0°C to 300 °C (1°C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1°C) Valve Temperature Settings: 0°C to 300 °C (1°C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1°C) Transfer Line Temperature Settings: 0°C to 350 °C (1°C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1°C) Transfer Line Temperature Settings: 0°C to 350 °C (1°C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1°C) Transfer Line Temperature Settings: 0°C to 350 °C (1°C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1°C) Transfer Line Temperature Settings: 0°C to 350 °C (1°C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1°C) Temperature settings: -40 °C to 140 °C (Valve temperature +15 °C to 350 °C (Accuracy ±1°C) Temperature settings: -40 °C to 140 °C (Valve temperature +250 °C); Room temperature -45 °C to 140 °C (Valve temperature -4	Tube Desorption Flow Rate	Settings: 20 mL/min to 200 mL/min (1 mL/min increments; Accuracy ±2 mL/min)			
TENAX-TA 60-80 mesh (60 mg) is standard.	Tube Desorption Time	Settings: 0 min to 240 min (0.01 min increments)			
Carbopack" (50 mg) + Carbosieve* (10 mg) are optionally available. Carboxen 1000 (70 mg) is optionally available. Settings: -0°C to 350 °C (1°C increments); Control: 0°C to 350 °C (Accuracy ±1°C) Settings: -40°C to 380 °C (1°C increments) Control: Room temperature -50°C to 80°C (Valve temperature -250°C); Room temperature -45°C to 80°C (Valve temperature -45°C to 300°C (Valve temperature -45°C to 350°C (Valve temperature -45°C to 140°C (Valve temperature -45°C to 140°C (Valve temperature -45°C to 140°C (Valve temperature -250°C); Room temperature -45°C to 140°C (Valve temperature -250°C); Room temperature -45°C to 140°C (Valve temperature -250°C); Room temperature -45°C to 140°C (Valve temperature -50°C to 140°C (Valve temperature -250°C); Room temperature -45°C to 140°C (Valve temperature -50°C); Room temperature -45°C to 140°C (Valve temperatur	Trap Size	Outer diameter: 1/8" (3.2 mm); Inner diameter: 2 mm; Length: 102 mm SilcoNert® 2000 stainless steel tube rendered inert			
Carboxen 1000 (70 mg) is optionally available. Trap Desorption Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1 °C) Trap Cooling Temperature Settings: -40 °C to 80 °C (1 °C increments) Control: Room temperature −50 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −45 °C to 80 °C (Valve temperature −250 °C); Room temperature −15 °C to 300 °C (10 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Folo	Trap Adsorbent	TENAX-TA 60–80 mesh (60 mg) is standard.			
Trap Desorption Temperature Settings: 0°C to 350 °C (1°C increments); Control: 0°C to 350 °C (Accuracy ±1°C) Trap Cooling Temperature Settings: -40 °C to 80 °C (1°C increments); Control: Room temperature -45 °C to 80 °C (Valve temperature <250 °C); Room temperature -45 °C to 80 °C (Valve temperature <250 °C); Room temperature -45 °C to 80 °C (Valve temperature <250 °C); Room temperature -45 °C to 80 °C (Valve temperature <250 °C); Room temperature -45 °C to 80 °C (Valve temperature <250 °C); Room temperature -45 °C to 80 °C (Valve temperature valve, motorized Split Ratio 1:5 to 1:200 Sample Path SilcoNert 2000 Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mit; Variable volume added: 4 mit to 2000 mt. Dry Purge (TD-30R) Temperature settings: -40 °C to 140 °C (1 °C increments); Control: Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C t		Carbopack™ (50 mg) + Carbosieve® (10 mg) are optionally available.			
Settings: -40 °C to 80 °C (1 °C increments)		Carboxen 1000 (70 mg) is optionally available.			
Control: Room temperature –50 °C to 80 °C (Valve temperature <250 °C); Room temperature –45 °C to 80 °C (Valve temperature > 250 °C); (Accuracy ±1 °C) Split Ratio 1:5 to 1:200 Sample Path SilcoNert 2000 Miching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature 5 ettings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature 5 ettings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature 5 ettings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge (TD-30R) Temperature settings: –40 °C to 140 °C (1 °C increments) Control: Room temperature <250 °C); Room temperature <45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature	Trap Desorption Temperature	Settings: 0 °C to 350 °C (1 °C increments); Control: 0 °C to 350 °C (Accuracy ±1°C)			
Cyalve temperature > 250 °C); (Accuracy ±1 °C) Split Ratio 1:5 to 1:200 Sample Path SiicoNert 2000 Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge (TD-30R) Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature >50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room t	Trap Cooling Temperature	Settings: -40 °C to 80 °C (1 °C increments)			
Split Ratio 1:5 to 1:200 Sample Path SilcoNert 2000 Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Titernal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Control: Room temperature -50 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature +15 °C to 350 °C (Room temperature +1		Control: Room temperature –50 °C to 80 °C (Valve temperature <250 °C); Room temperature –45 °C to 80 °C			
Sample Path SilcoNert 2000 Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Tremperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature -45 °C to 140 °C (Valve temperature -250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature -45 °C to 140 °C (Valve temperature >250 °C); Room temperature <250 °C); Room temperature >250 °C); Room temperature <250 °C); Room temperature >250 °C); Room temperature <250 °C); Room temp		(Valve temperature > 250 °C); (Accuracy ±1 °C)			
Switching Valve 6-port, 2-position, high temperature valve, motorized Joint Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge (TD-30R) Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature <250 °C); Room temperature <250 °C); Room temperature /5 °C to 140 °C (Valve temperature <250 °C); Room temperature /5 °C to 140 °C (Valve temperature <250 °C); Room temperature /5 °C to 140 °C (Valve temperature <250 °C); Room temperature /5 °C to 140 °C (Valve tempe	Split Ratio	1:5 to 1:200			
Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Valve Temperature Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C) Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Dry Purge (TD-30R) Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature -45 °C to 140 °C (Valve temp	Sample Path	SilcoNert 2000			
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Transfer Line Temperature Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C) Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature	Joint Temperature	Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C)			
Internal Standard Added (TD-30R) Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature <250 °C); Room temperature /250 °C); Room temperatu	Valve Temperature	Settings: 0 °C to 300 °C (1 °C increments); Control: Room temperature +15 °C to 300 °C (Accuracy ±1 °C)			
Temperature settings: -40 °C to 140 °C (1 °C increments) Control: Room temperature -50 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature 0 value -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temperature 0 value -45 °C to 140 °C (Valve temperature <250 °C); Room temperature -45 °C to 140 °C (Valve temperature <250 °C); Room temper	Transfer Line Temperature	Settings: 0 °C to 350 °C (1 °C increments); Control: Room temperature +15 °C to 350 °C (Accuracy ±1 °C)			
Control: Room temperature –50 °C to 140 °C (Valve temperature <250 °C); Room temperature –45 °C to 140 °C (Valve temperature >250 °C); (Accuracy ±1 °C) Flow rate: 20 mL/min to 200 mL/min (1 mL/min increments); Time: 0 min to 30 min (0.01 min increments) Carrier Gas High-purity helium or nitrogen, controlled by the advanced flow controller (AFC) built into the GC Purge Gas High-purity helium or nitrogen, controlled by the mass flow controller (MFC) built into the TD PC Interface USB Control Software TD-30 Control Software Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Temperature 18 °C to 28 °C; Relative humidity 20 % to 70 % Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Internal Standard Added (TD-30R)	Fixed volume added: 0.5 mL; Variable volume added: 4 mL to 2000 mL			
(Valve temperature >250 °C); (Accuracy ±1 °C) Flow rate: 20 mL/min to 200 mL/min (1 mL/min increments); Time: 0 min to 30 min (0.01 min increments) Carrier Gas High-purity helium or nitrogen, controlled by the advanced flow controller (AFC) built into the GC Purge Gas High-purity helium or nitrogen, controlled by the mass flow controller (MFC) built into the TD PC Interface USB Control Software TD-30 Control Software Ontrol Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Dry Purge (TD-30R)	Temperature settings: -40 °C to 140 °C (1 °C increments)			
Flow rate: 20 mL/min to 200 mL/min (1 mL/min increments); Time: 0 min to 30 min (0.01 min increments) Carrier Gas High-purity helium or nitrogen, controlled by the advanced flow controller (AFC) built into the GC Purge Gas High-purity helium or nitrogen, controlled by the mass flow controller (MFC) built into the TD PC Interface USB Control Software TD-30 Control Software Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 x D690 x H470 mm, TD-30: W580 x D550 x H470 mm		Control: Room temperature –50 °C to 140 °C (Valve temperature <250 °C); Room temperature –45 °C to 140 °C			
Carrier Gas High-purity helium or nitrogen, controlled by the advanced flow controller (AFC) built into the GC Purge Gas High-purity helium or nitrogen, controlled by the mass flow controller (MFC) built into the TD PC Interface USB Control Software TD-30 Control Software Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 x D690 x H470 mm, TD-30: W580 x D550 x H470 mm		(Valve temperature >250 °C); (Accuracy ±1 °C)			
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PC Interface USB Control Software Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Carrier Gas	High-purity helium or nitrogen, controlled by the advanced flow controller (AFC) built into the GC			
Control Software Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Purge Gas	High-purity helium or nitrogen, controlled by the mass flow controller (MFC) built into the TD			
Control Software Operating Environment Microsoft® Windows® 7/10 (64/32 bit) Environment for Guaranteed Performance Temperature 18 °C to 28 °C; Relative humidity 20 % to 70 % Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	PC Interface	USB			
Environment for Guaranteed Performance Temperature 18 °C to 28 °C; Relative humidity 20 % to 70 % Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 x D690 x H470 mm, TD-30: W580 x D550 x H470 mm	Control Software	TD-30 Control Software			
Power Supply 100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max. Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Control Software Operating Environment	Microsoft® Windows® 7/10 (64/32 bit)			
Size TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm	Environment for Guaranteed Performance				
· ·	Power Supply	100 V AC / 120 V AC / 220 V AC / 240 V AC, 50/60 Hz, 1200 VA max.			
Weight TD-30R: 49 kg, TD-30: 48 kg	Size	TD-30R: W720 × D690 × H470 mm, TD-30: W580 × D550 × H470 mm			
	Weight	TD-30R: 49 kg, TD-30: 48 kg			

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First Edition: January, 2019 Second Edition: October 2022



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