

## EVALUATION OF MONITORING SYSTEM NETWORK PERFORMANCE

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**Abstract** – Nowadays the measurements take place an important role in our life. In order to prevent some unpleasant situations, we try day by day to assure environmental conditions that protect us against some accidents due to explosion or high level of toxicity that can occur, in working environment and confined spaces. The article presents the statistical characteristics of a monitoring system consisting of 17 calibration stations connected to a server in a secured network and a number of 373 gas analysers. The measurement data, downloaded from each analyser are stored, analysed, processed, reported and archived for later documentation. The monitoring system, created by Dräger technology which assure a high protection of life within the sectors surrounding in the vicinity of wastewater plants, where we can find the gasses such as CH<sub>4</sub>, H<sub>2</sub>S, CO, lack of O<sub>2</sub> and so on. In order to demonstrate the performance of calibration stations, the performance parameters  $Z_{score}$  and  $E_n$  number were calculated using data from 40 gas analysers.

**Keywords:** monitoring network, gas analysers,  $Z_{score}$

### 1. INTRODUCTION

Quality of our life depends entirely on the air that we breath, the water that we drink, the food that grow from the earth and, in this respect, it's our duty and responsibility to preserve and protect the environment.

Having the scope to protect the life in the open areas and in confined spaces situated near the wastewaters, the organisation responsible for fresh water supply and waste water treatment starts a great project in which a number of 373 gas analysers were purchased.

Three types of gas analysers: Xam 5000, Xam 5600 and Xam 2500 are used to monitor simultaneously four gases: CH<sub>4</sub>, H<sub>2</sub>S, CO and O<sub>2</sub> and all these instruments are periodically tested and calibrated with 17 monitoring stations.

Each test station, type X-Dock, is connected to a server and all measurement data are transmitted in real time to a database where measurement information are centralized, stored, analysed, processed, reported and documented. This application has been a pioneer project in Europe and launched by Dräger for the first time in Romania.

Each test and calibration stations uses a reference

material [1], having a demonstrated traceability for CH<sub>4</sub> (2,5 ± 2 % rel.) % vol.; H<sub>2</sub>S (13,0 ± 5% rel) ppm, CO (48,0 ± 2 % rel) ppm, O<sub>2</sub> (18,0 ± 1 % rel.) % vol., where: for CH<sub>4</sub>, 5% vol. is equivalent of 100 %LEL; 1% vol. represents 10<sup>-6</sup> ppm.

### 2. OVERVIEW OF MONITORING SYSTEM

#### 2.1. Test and Calibration Station X-Dock

The monitoring system network consists of 373 multigas analysers which are tested and / or calibrated at regular interval using 17 X-Dock test equipment [2], located in different working point in Bucharest, covering an area of 285 km<sup>2</sup>.

Each X-Dock station is connect to a server by a unique IP address and send in real time the measurement and event data downloaded from gas analysers. An example of a system network is shown in Fig. 1.

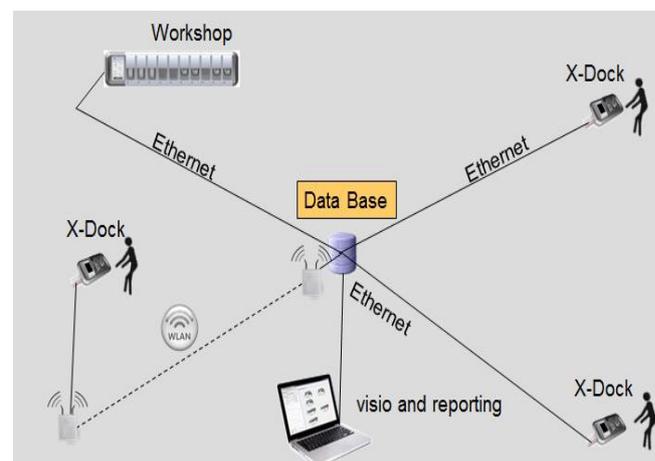


Fig. 1. Schematic representation of the monitoring system network in which each X-Dock station is connected to the server by a unique IP address.

X-Dock is an integrated touchscreen instrument [2] designed for calibration and testing of portable instruments and offers several functions like datalogger read out, quick test programs, certification printing. X-Dock and Xam 5X00.

The main parts of the measuring and control system are presented in Fig. 2.



Fig. 2. X-Dock station and Xam gas analyser.

### 2.2. X-Dock Manager - Evaluation and Data Management Software

The software designed for administrating, viewing and analyzing the database is X-Dock Manager. It is installed on a server that uses a static IP address and is accessible for all clients. The software offers asset management and documentation of a one central database, enables remote information, automatic e-mail reports, graphical overview of tests and statistical values about customer's fleet status. The database is structured and visualized by the X-Dock Manager: test results of gas detection, read out datalogger of X-Dock, reports generated according to a template, statistical evaluation of measurement data. Direct overview of X-Dock station and Xam gas analyzers are visible in different tabs of this software: "Device, Stations, Users, Reports, Device assignment" presented in Fig. 3, Fig. 4, Fig. 5.



Fig. 3. General overview of the testing and calibration system.

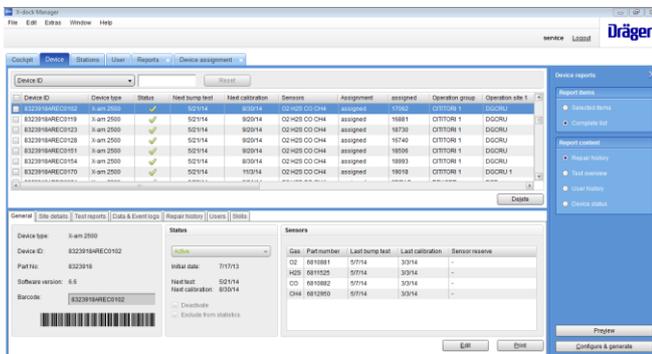


Fig. 4. Device tab; identification and status of each gas analyser.

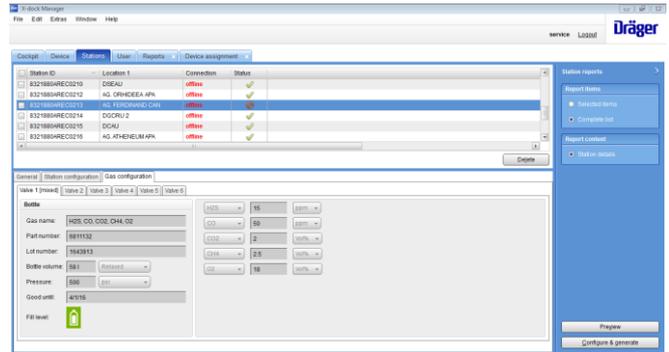


Fig. 5. Stationtab; detailed informations about X-Dock system.

### 3. RESULTS AND CONCLUSIONS

In order to demonstrate the uniformity of calibration results, had been randomly chosen a number of 40 measuring instruments, 23 Xam 5000 gas analysers and 17 Xam 5600gas analyser.

All selected gas analyzers had been automatically calibrated before, using the 17 X-Dock calibration stations.

The performance levels of calibrations were evaluated using the measurement results of gas analysers, through the calculated performance parameters  $Z_{score}$  and  $E_n$  number [3], using the aggregated formula (1):

$$Z_{score} = \left| \frac{\bar{y} - \gamma_{CRM}}{\sqrt{u^2_{\bar{y}} + u^2_{CRM}}} \right|, E_n = \left| \frac{\bar{y} - \gamma_{CRM}}{\sqrt{U^2_{\bar{y}} + U^2_{CRM}}} \right| \quad (1)$$

where  $\gamma$  - represents the volume fraction of gas component and  $u$  represent the associated uncertainty.

- a) for  $Z_{score}$ 
  - $|z| \leq 2$ ; the score indicates "satisfactory" performance
  - $2 < |z| < 3$ ; the score indicates "questionable" performance
  - $|z| \geq 3$ ; the score indicates "unsatisfactory" performance
- b) for  $E_n$  number
  - $|E_n| \leq 1$ ; the score indicates "satisfactory" performance
  - $|E_n| > 1$ ; the score indicates "unsatisfactory" performance

The performance parameters calculated for the selected gas analysers, type Xam 5000 and Xam 5600 are presented as results of measurements performed with a standard gas mixture with the following concentration: 2,5 % vol.  $CH_4$  / 13 ppm  $H_2S$  / 48 ppm  $CO$  / 18 % vol.  $O_2$ :

- Table 1 presents obtained results for methane ( $CH_4$ );
- in Table 2 are presented the measurement results for hydrogen sulfide ( $H_2S$ ) while
- in Table 3 there are the results for carbon monoxide ( $CO$ ) measurements.

Table 1. Performance parameters  $Z_{score}$  and  $E_n$  calculated for a standard gas mixture with 2,5 % vol.  $CH_4$  concentration.

Station No	$Z_{score}$	$E_n$ number	Station No	$Z_{score}$	$E_n$ number
1	0.717	0.359	24	-1.406	-0.703
2	0.375	0.187	25	-1.100	-0.550
3	0.800	0.400	26	0.819	0.410
4	-0.568	-0.284	27	-0.728	-0.364
5	0.181	0.090	28	0.930	0.465
6	0.988	0.494	29	-0.717	0.359
7	-0.651	-0.325	30	-1.717	-0.589
8	-0.819	-0.410	31	-1.310	-0.655
9	-0.728	-0.364	32	-1.250	-0.625
10	1.280	0.640	33	-0.800	-0.400
11	0.467	0.234	34	-1.086	-0.543
12	0.717	0.359	35	-1.177	-0.589
13	-0.568	-0.284	36	1.331	0.665
14	0.391	0.195	37	-0.860	-0.430
15	0.926	0.463	38	-1.268	-0.634
16	1.248	0.624	39	1.100	0.550
17	0.930	0.465	40	-0.522	-0.261
18	-0.955	-0.478			
19	0.860	0.430			
20	1.177	0.589			
21	0.988	0.494			
22	1.136	0.568			
23	1.036	0.518			

Table 2. Performance parameters  $Z_{score}$  and  $E_n$  calculated for a standard gas mixture with 13 ppm  $H_2S$  concentration.

Station No	$Z_{score}$	$E_n$ number	Station No	$Z_{score}$	$E_n$ number
1	-0.646	-0.323	24	0.445	0.223
2	-0.442	-0.221	25	-0.421	-0.210
3	-0.633	-0.316	26	0.552	0.276
4	-0.597	-0.298	27	0.471	0.235
5	-0.628	-0.314	28	0.530	0.265
6	-0.488	-0.244	29	-0.541	-0.270
7	-0.153	-0.076	30	-0.654	-0.327
8	-0.258	-0.129	31	0.371	0.185
9	-0.239	-0.119	32	-0.644	-0.322
10	0.593	0.296	33	-0.622	-0.311
11	-0.279	-0.140	34	0.541	0.270
12	0.730	0.365	35	-0.599	-0.300
13	0.798	0.399	36	-0.445	-0.223
14	-0.241	-0.120	37	-0.421	0.210
15	-0.237	-0.119	38	-0.785	-0.393
16	0.663	0.332	39	-0.859	-0.429
17	0.798	0.399	40	-0.726	-0.363
18	-0.279	-0.140			
19	-0.382	-0.191			
20	0.718	0.359			
21	0.655	0.327			
22	0.735	0.367			
23	-0.461	-0.231			

Table 3. Performance parameters  $Z_{score}$  and  $E_n$  calculated for a standard gas mixture with 48 ppm CO concentration.

Station No	$Z_{score}$	$E_n$ number	Station No	$Z_{score}$	$E_n$ number
1	-0.698	-0.349	24	0.591	0.295
2	-0.445	-0.222	25	0.524	0.262
3	0.885	0.443	26	-0.828	-0.414
4	0.739	0.370	27	-0.722	-0.361
5	-0.701	-0.350	28	-0.617	-0.309
6	-0.404	-0.202	29	0.773	0.387
7	0.722	0.361	30	0.423	0.212
8	-0.741	-0.370	31	0.828	0.414
9	0.739	0.370	32	-0.722	-0.361
10	0.820	0.410	33	0.484	0.242
11	-0.465	-0.232	34	-0.320	-0.160
12	0.789	0.395	35	-0.542	-0.271
13	0.542	0.271	36	0.707	0.353
14	0.858	0.429	37	0.266	0.133
15	-0.707	-0.353	38	-0.505	-0.252
16	0.781	0.391	39	0.609	0.305
17	-0.605	-0.302	40	0.393	0.197
18	-0.789	-0.395			
19	-0.505	-0.252			
20	0.372	0.186			
21	-0.234	-0.117			
22	0.803	0.402			
23	0.765	0.383			

Additionally, in order to better understand the good functioning of this network, have been used, few measuring standards having small differences in volume fractions, by these test and calibration stations and a number of gas analysers where used in measurements [4], [5], [6]. The  $Z_{score}$  and  $E_n$  number where calculated and all results shown that  $Z_{score}$  is smaller than 2 and  $E_n$  number is smaller than 1. The results are presented in Table 4 for  $CH_4$ , in Table 5 for  $H_2S$  and in Table 6 for CO.

Table 4. Assigned values & Performance parameters  $Z_{score}$  and  $E_n$  calculated for methane.

Station no.	$x_a \pm u_c$ [ppm]	$x_i$ [ppm]	$u_c$ [ppm]	$Z_{score}$	$E_n$ number
1	57.450 $\pm 0.623$	57.6	0.815	0.146	0.073
2		57.2	0.823	-0.242	-0.121
5		57.0	0.851	-0.427	-0.213
8		55.9	1.207	-1.141	-0.571
10		58.7	1.085	0.999	0.500
11		57.3	0.815	-0.146	-0.073
12		57.6	0.815	0.146	0.073
15		57.7	0.823	0.242	0.121
16		58.6	1.047	0.944	0.472
18		55.9	1.207	-1.141	-0.571
19		57.8	0.835	0.336	0.168
21		58.7	0.917	0.649	0.325
23		58.1	0.893	0.597	0.299
3		57.974 $\pm 0.644$	58.4	0.851	0.400
4	56.9		1.023	-0.887	-0.444
6	58.7		0.917	0.649	0.325
7	56.8		1.059	-0.946	-0.473
9	56.7		1.097	-1.000	-0.500

Station no.	$x_a \pm u_c$ [ppm]	$x_i$ [ppm]	$u_c$ [ppm]	$Z_{score}$	$E_n$ number
13		56.9	1.023	-0.887	-0.444
14		57.9	0.816	-0.070	-0.035
17		58.6	0.892	0.570	0.285
20		59.1	1.043	0.920	0.460
22		59.0	1.008	0.859	0.429
24	50.417 $\pm 0.845$	52.2	1.282	1.161	0.581
25		51.3	0.918	0.708	0.354
36		48.1	1.540	-1.319	-0.659
38		51.7	1.064	0.944	0.472
39		48.7	1.251	-1.137	-0.568
40		50.5	0.765	0.073	0.037
26	57.660 $\pm 0.747$	55.9	1.300	-1.174	-0.587
29		57.6	0.811	-0.054	-0.027
31		58.8	1.044	0.888	0.444
34		58.2	0.868	0.471	0.236
37		57.8	0.814	0.127	0.063
27	58.433 $\pm 0.724$	58.3	0.818	-0.122	-0.061
28		56.4	1.429	-1.269	-0.635
30		59.1	0.901	0.577	0.288
32		59.3	0.956	0.723	0.361
33		58.4	0.815	-0.031	-0.015
35		59.1	0.901	0.577	0.288

Table 5. Assigned values & Performance parameters  $Z_{score}$  and  $E_n$  calculated for hydrogen sulfide.

Station no.	$x_a \pm u_c$ [ppm]	$x_i$ [ppm]	$u_c$ [ppm]	$Z_{score}$	$E_n$ number
1	12.938 $\pm 0.333$	12.68	0.358	-0.529	-0.264
2		12.79	0.336	-0.314	-0.157
5		12.69	0.355	-0.510	-0.255
8		12.88	0.327	-0.125	-0.063
10		13.29	0.383	0.693	0.346
11		12.87	0.327	-0.146	-0.073
12		13.37	0.410	0.818	0.409
15		12.89	0.326	-0.104	-0.052
16		13.33	0.396	0.757	0.379
18		12.87	0.327	-0.146	-0.073
19		12.82	0.332	-0.252	-0.126
23		12.78	0.338	-0.334	-0.167
3	12.996 $\pm 0.342$	12.59	0.399	-0.773	-0.387
4		12.61	0.392	-0.742	-0.371
7		12.83	0.337	-0.346	-0.173
9		12.79	0.344	-0.425	-0.213
13		13.31	0.370	0.623	0.311
17		13.31	0.370	0.623	0.311
20		13.26	0.357	0.534	0.267
22		13.27	0.359	0.522	0.276
6	12.793 $\pm 0.361$	12.57	0.345	-0.447	-0.224
14		12.69	0.326	-0.213	-0.106
21		13.12	0.371	0.631	0.315
24		12.66	0.418	-0.830	-0.415
25	13.115 $\pm 0.355$	13.32	0.346	0.415	0.207
26		12.57	0.452	-0.948	0.474
29		13.42	0.37	0.596	0.298
31		12.72	0.397	-0.741	-0.371
34		12.58	0.448	-0.935	-0.468
36		13.34	0.35	0.452	0.226
37		12.68	0.411	-0.801	-0.400
38		13.65	0.449	0.936	0.468
39		13.73	0.482	1.029	0.515

Station no.	$x_a \pm u_c$ [ppm]	$x_i$ [ppm]	$u_c$ [ppm]	$Z_{score}$	$E_n$ number
40	13.103 $\pm 0.372$	13.59	0.425	0.858	0.429
27		12.54	0.458	-0.954	-0.477
28		12.49	0.479	-1.011	-0.505
30		13.42	0.371	0.603	0.301
32		13.41	0.368	0.586	0.293
33		13.39	0.363	0.552	0.276
35		13.37	0.357	0.517	0.258

Table 6. Assigned values & Performance parameters  $Z_{score}$  and  $E_n$  calculated for carbon monoxide.

Station no.	$x_a \pm u_c$ [ppm]	$x_i$ [ppm]	$u_c$ [ppm]	$Z_{score}$	$E_n$ number	
1	47.916 $\pm 0.512$	47.32	0.591	-0.762	-0.381	
2		47.59	0.516	-0.448	-0.224	
5		47.48	0.542	-0.585	-0.292	
6		47.63	0.508	-0.397	-0.198	
8		47.27	0.608	-0.813	-0.406	
10		48.83	0.713	1.041	0.520	
11		47.57	0.520	-0.474	-0.237	
12		48.79	0.696	1.011	0.505	
14		48.88	0.735	1.076	0.538	
15		47.31	0.594	-0.772	-0.386	
16		48.78	0.692	1.003	0.502	
18		47.21	0.630	-0.870	-0.435	
19		47.53	0.529	-0.178	-0.089	
21		47.79	0.486	-0.223	-0.112	
23		48.76	0.684	0.988	0.494	
3		48.739 $\pm 0.506$	49.12	0.530	0.520	0.260
4			48.93	0.495	0.270	0.135
7			48.91	0.492	0.242	0.121
9	48.93		0.495	0.269	0.135	
13	48.71		0.482	-0.041	0.020	
17	47.76		0.743	-1.087	-0.543	
20	48.54	0.496	-0.280	-0.140		
22	49.01	0.507	0.378	0.189		
24	47.734 $\pm 0.508$	47.44	0.508	-0.408	-0.204	
25		47.51	0.497	-0.315	-0.157	
26		48.84	0.799	1.168	0.584	
29		47.23	0.561	-0.665	-0.333	
31		47.16	0.583	-0.741	-0.371	
34		48.29	0.578	0.723	0.362	
36		47.31	0.539	-0.572	-0.286	
37		47.76	0.480	0.038	0.019	
38		48.47	0.641	0.900	0.450	
39		47.42	0.513	-0.434	-0.217	
40		47.64	0.483	-0.134	-0.067	
27		48.480 $\pm 0.531$	48.91	0.542	0.566	0.283
28	48.79		0.514	0.419	0.210	
30	48.81		0.618	-0.822	-0.411	
32	48.91		0.542	0.566	0.283	
33	47.75		0.640	-0.877	-0.439	
35	48.71		0.500	0.315	0.158	

The following figures graphically show the associated uncertainties for the different volume fractions which have been used by the systems (consisting of test and calibration stations and the gas analyzers). Fig. 6 to Fig. 10 show the results for hydrogen sulfide based on the measurement results presented in Table 5, while Fig. 11 to Fig. 14 presents

the measurement results for carbon monoxide based on the measurement results presented in Table 6.

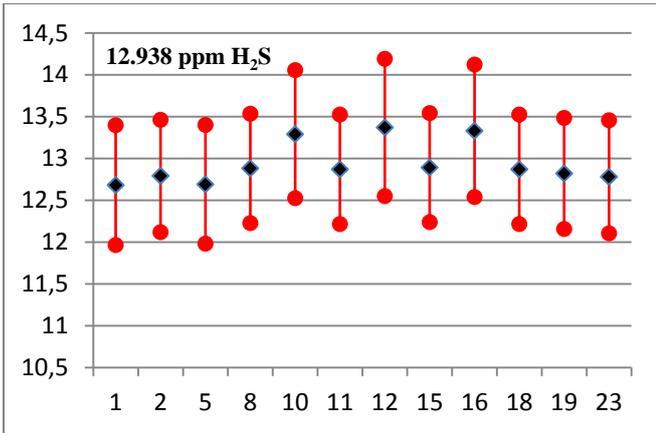


Fig. 6. Measurement results for 12.938 ppm H<sub>2</sub>S concentration

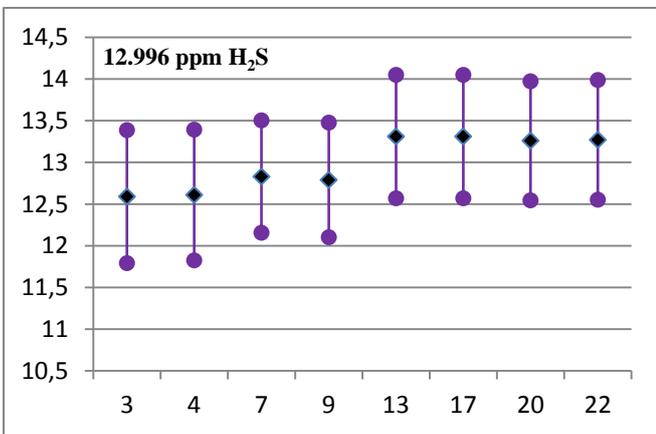


Fig. 7. Measurement results for 12.996 ppm H<sub>2</sub>S concentration

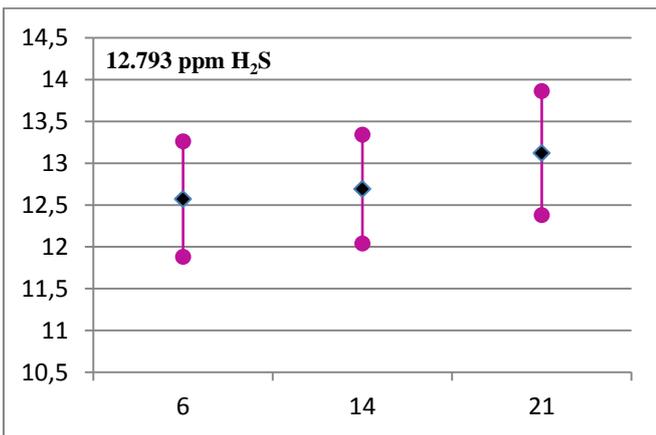


Fig. 8. Measurement results for 12.793 ppm H<sub>2</sub>S concentration

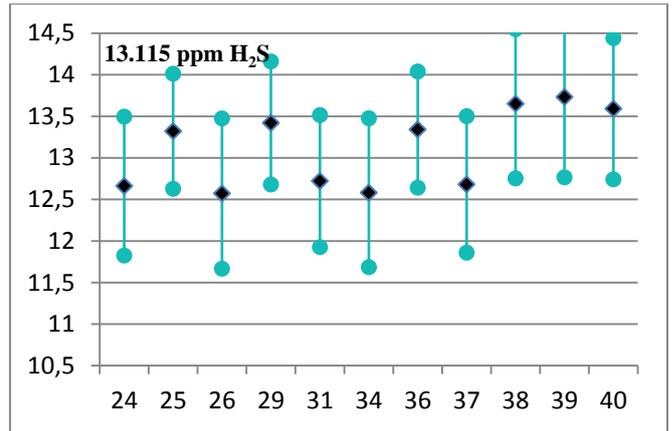


Fig. 9. Measurement results for 13.115 ppm H<sub>2</sub>S concentration

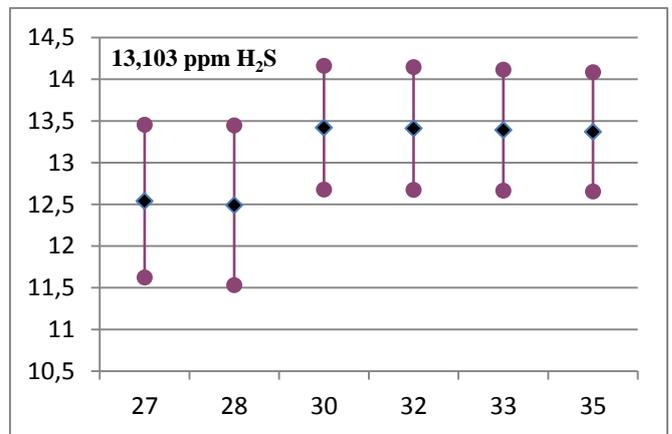


Fig. 10. Measurement results for 13.103 ppm H<sub>2</sub>S concentration

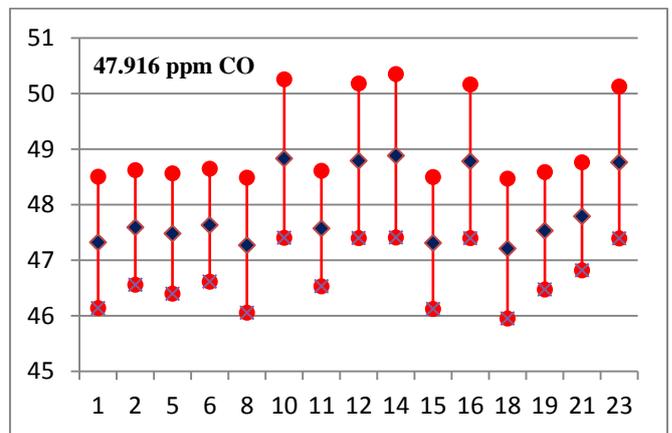


Fig. 11. Measurement results for 47.916 ppm CO concentration

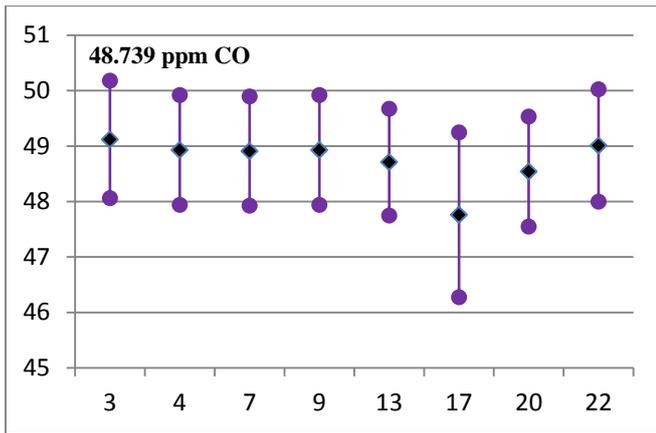


Fig. 12. Measurement results for 48.739 ppm CO concentration

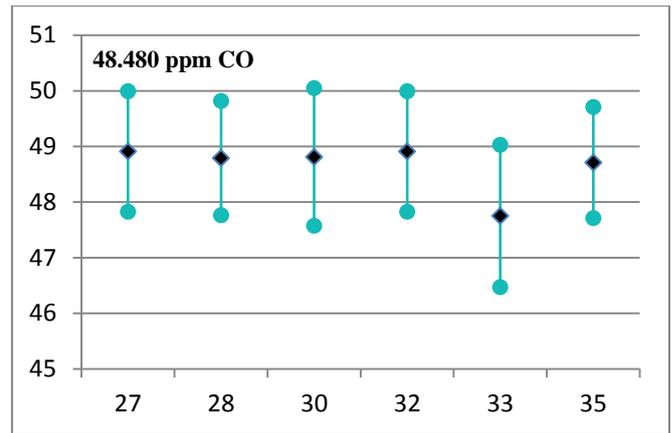


Fig. 14. Measurement results for 48.480 ppm CO concentration

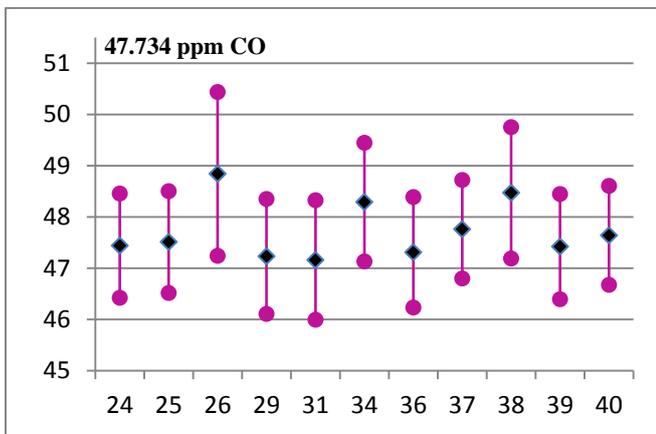


Fig. 13. Measurement results for 47.734 ppm CO concentration

This means that the entire monitoring system works according to the purposes it has been designed, the results of measurements, performed with these gas analyzers, checked and calibrated periodically, by these X-Dock monitoring stations, provide reliable measurements, with high accuracy, proving that the developed system works as a whole, at a high quality standard.

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