

## Industrial Trials of the Automatic Device Controlling the Concentration of Dicyanoaurate in Alkaline Solutions at Gold Mills

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### Abstract

The article presents the results of laboratory and industrial trials of the automatic device controlling  $[Au(CN)_2]^-$  in alkaline cyanide solutions at JSC Irgiredmet (gravity concentrate intensive leaching installation) and Svetlinskaya Gold Mill, the Gold Mining Company UGC (installation for autoclave gold desorption out of active carbon and electrolysis). The trials have been conducted to evaluate the measurement accuracy of the device versus the atomic absorption method. The authors assessed the findings.

**Keywords:** gold, concentration measurement, ion-selective electrode, device, continuous measurement, cyanide solutions.

### INTRODUCTION

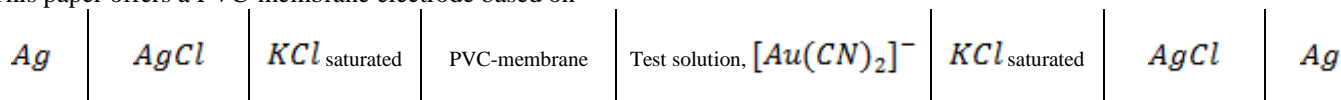
At present, operating analytical grade control at different technological stages plays a big role for the optimum process. Such control is highly needed in the following sections: cyanidation, sorption, desorption of gold out of active carbon, and electrolysis. This information makes it possible to determine the degree of metals transition from the ore or the concentrate into the liquid phase of the pulp, as well as from the pulp solution to the sorbent and, finally, their recovery to the commercial product. Gold samples are collected at the main process stages by automatic samplers or manually. Dissolved gold concentration varies from 0.1 to 1000 mg/l and more.

Atomic absorption analyzers are most widely spread in the industry [1, 4]. Measurement accuracy is their advantage, but these analyzers are not suitable for the operating control systems. Thus, the development of the device that could measure gold content in solutions in real time is an urgent task.

One of the most common ways to measure concentrations rapidly is to apply ion-selective electrodes (ISE) [3, 5, 10]. It is popular in Russia as well [2]. In literature, the number of works devoted to the determination of the gold-cyanide complex  $[Au(CN)_2]^-$  by means of ISE is limited [6-9].

### METHODS

This paper offers a PVC-membrane electrode based on



tetraoctylammonium bromide with a wide concentration range from 1 mg/l to 1000 mg/l and more. The device for the automatic control of gold concentration in cyanide solutions based on this ISE has been also developed [12]. Besides, the paper contains preliminary studies of the electrode with the above-mentioned membrane [11].

The components used to produce the ISE plasticised membrane are as follows: PVC powder, tetrahydrofuran (THF), and dibutyl phthalate (DBP). A quaternary ammonium salt – tetraoctylammonium dicyanoaurate – was used as an electrode active component. The PVC-membrane was manufactured according to a well-known method [10].

Figure 1 shows the electrode used in the trials.

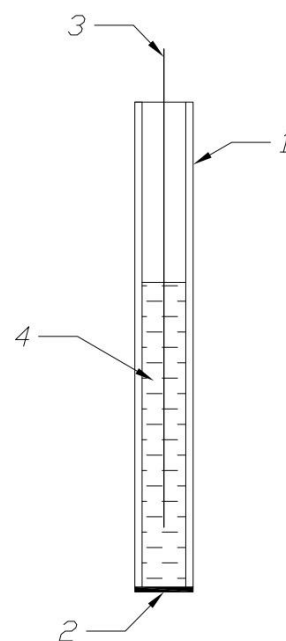


Figure 1. 1 – casing, 2 – ion-selective membrane, 3 – terminal, 4 – KCl solution 3M.

Membrane potentials were measured by means of the following galvanic circuit:

Trials were conducted in three stages. On the first stage, the measurements were taken in the hydrometallurgy laboratory at

JSC Irgiredmet. The second and the third stages were devoted to the evaluation of functional ability in the analytical laboratory at Svetlinskaya Gold Mill, JSC UGC, and directly in the waste solutions flow of the electrolysis section.

The patent-based automatic device was used during laboratory measurements [12]. The device contained the following elements:

- Measuring and comparative electrode input module OWEN MV110-224.pH;
- Panel programmable controller OWEN SPK107;
- Electromagnetic stirrer Ecros PE 6100;
- Comparative Brown electrode EVL 1M3.1;
- Measuring electrode,  $[Au(CN)_2]^-$  ion-sensitive;
- Measurement cell, 50 ml.

The patent-based device [12] with the below-mentioned elements was also used for measurements in the flow:

- Programmable controller Siemens S7 1200 with input/output modules;
- Industrial converter P-216;
- Magnetic stirrer;
- Measuring electrode,  $[Au(CN)_2]^-$  ion-sensitive;
- Measurement cell, 50 ml;
- Valve block;
- Calibration solution vessels.

## RESULTS

The first stage took place in the hydrometallurgy laboratory at JSC Irgiredmet. The measurement object: cyanide gold-bearing solutions, obtained by cyanation of gravity concentrates with the following characteristics:

- Au concentration, mg/l: 142.7
- Ag concentration, mg/l: 33.50
- Fe concentration, mg/l: 16.93
- Cu concentration, mg/l: 1.29
- NaCN concentration, g/l: 10
- pH: 12.4

Reference solutions for the measurements were produced by optional dilution of the feed solution maintaining NaOH and NaCN background.

The predetermined device calibration was performed in two points using the gold-bearing cyanide feed solution and the solution after its tenfold dilution.

The measurement cell with the measuring and comparative electrodes was successively filled with solutions, produced by the optional dilution of the feed solution by independent experts. The results were displayed on the device. In parallel, the same solutions were transported to the test analytic center to measure gold concentration by the atomic absorption method.

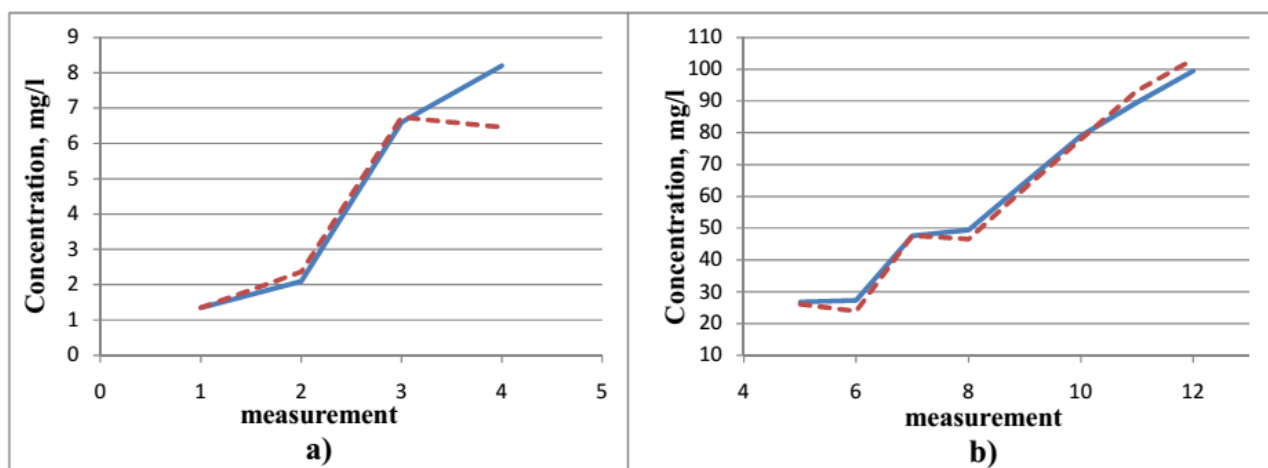
The results were evaluated in the test analytic center at JSC Irgiredmet. The atomic absorption method according to MA IAC-58-2004 (FR.1.31.2014.18474) KHA was used as a standard measurement method applying SOLAARS2 AA System and AA240 FS AA240 FS spectrometers.

The results of measuring the gold concentration in calibration solutions based on the atomic absorption analysis are shown in Table 1.

**Table 1.** Concentration in calibration solutions.

	Calibration solution No. 1	Calibration solution No. 2
Number of parallel measurements	3	3
Expected value, mg/l	14.1	142.7
Standard deviation, mg/l	0.1	2.73
0.95 confidence interval, mg/l	0.43	11.73

The comparative results of the measurements by the automatic control device and the analytical center are shown in Figure 2.



**Figure 2.** Comparative measurement chart.

The full line shows the results of atomic absorption measurements, the dashed line shows the results of the device.

a) The results within the range from 1 to 10 mg/l, b) the results within the range from 10 to 100 mg/l.

While measuring, the temperature of the solutions amounted to  $26 \pm 1$  °C and was almost the same with the calibration solutions. Thus, the influence of temperature on the results was the least. The fixed background concentrations of *NaCN* and *NaOH* did not influence the measurements. The errors of the measurements from Figure 2 are presented in Table 2. Atomic absorption and device measurements were compared.

**Table 2.** Measurement errors.

Measurement range, mg/l	Average relative error, %	Average absolute error, mg/l
1-10	9	0.55
10-100	4	2.1

14.1 mg/l and 143 mg/l solutions were subject to parallel measurements. The results are shown in Table 3.

**Table 3.** Measurement results.

	Solution No. 1	Solution No. 2
Number of parallel measurements	3	3
Measurement No. 1, mg/l	14.4	143.5
Measurement No. 2, mg/l	13.8	139.4
Measurement No. 3, mg/l	13.5	138
Expected value, mg/l	13.9	140.3
Standard deviation, mg/l	0.265	1.63
0.95 confidence interval, mg/l	1.14	7

The cyanide gold-bearing solutions, obtained at the industrial plant for high temperature gold desorption out of active carbons, was the measurement object on the second stage. The trials were carried out in the analytic laboratory at Svetlinskaya Gold Mill.

The atomic absorption method was taken as a standard one applying the atomic-absorption spectrometer Kvant-2A. Parallel sample measurements were conducted by the specialists from the Gold Mill analytical laboratory and the automatic control device.

The measurement procedure was as follows. The measurement cell with the measuring and comparative electrodes was successively filled with solutions, sampled from the plant for

high-temperature gold desorption out of active carbons. After measuring by the device, the solutions were transported to the laboratory to measure gold concentration by the atomic absorption method.

Table 4 shows the specification of the calibration solutions.

**Table 4.** Specification of the calibration solutions.

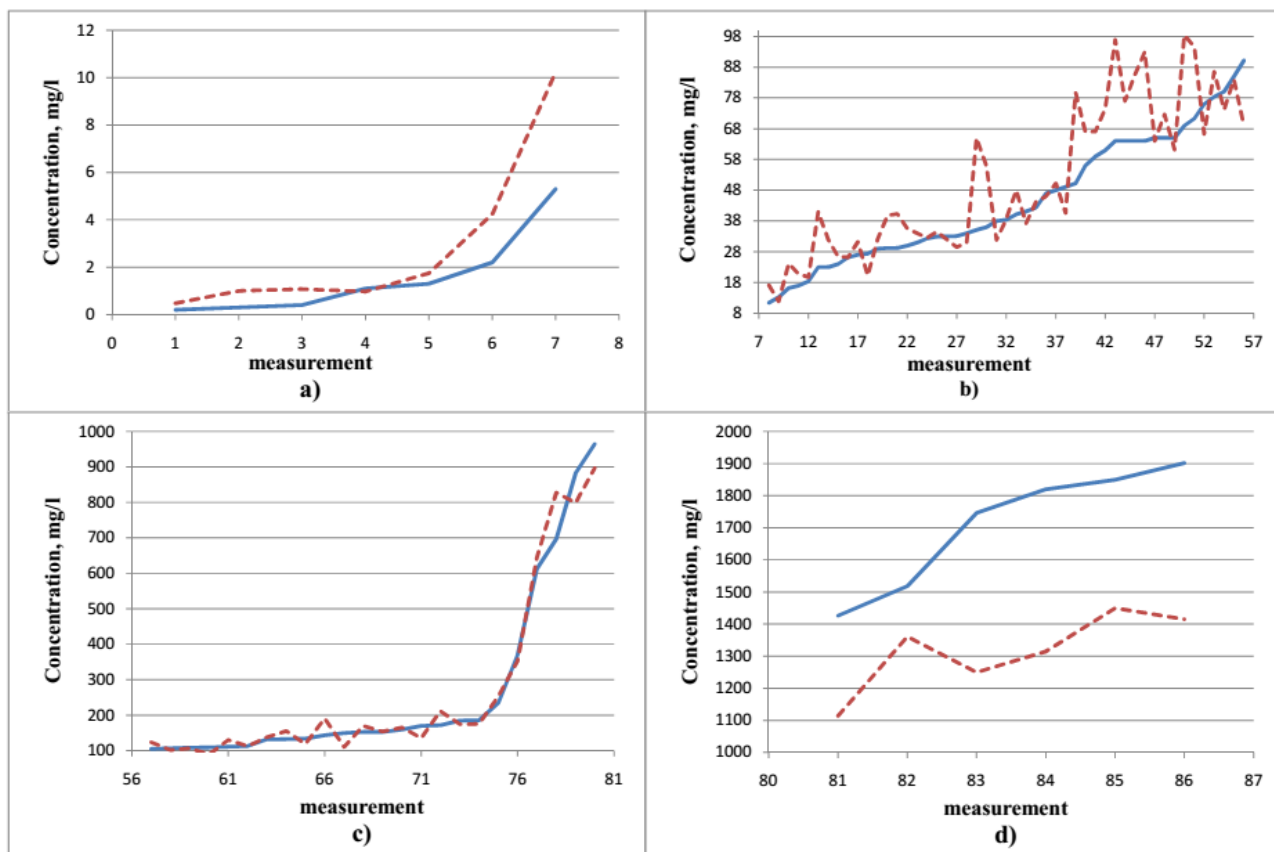
Calibration solution No.	1	2	3
Au concentration, mg/l	723.86	92.87	5.17
Ag concentration, mg/l	75	44	4.7
Cu concentration, mg/l	10	15.4	4
NaCN concentration, %	0.012	0.014	0.014
NaOH concentration, %	0.28	0.296	0.424
pH	11.35	11.27	11.42

The gold concentration measurement error was evaluated by the atomic absorption method at Svetlinskaya Gold Mill. Table 5 presents the results of measurement processing.

**Table 5.** Measurement processing results.

Solution No.	1	2	3
Number of parallel measurements	7	7	7
Expected value, mg/l	723.86	92.87	5.17
Standard deviation, mg/l	20.90	1.85	0.57
0.95 confidence interval, mg/l	51.15	4.52	1.40

The comparative results of the measurements by the automatic control device and the atomic absorption method under laboratory conditions are shown in Figure 3.



**Figure 3.** Comparative measurement chart. The full line shows the results of atomic absorption measurements, the dashed line shows the results of the device. a) The results within the range from 1 to 10 mg/l, b) the results within the range from 10 to 100 mg/l, c) the results within the range from 100 to 1000 mg/l, d) the results within the range from 1000 to 2000 mg/l.

Average errors of these measurements are shown in Table 6.

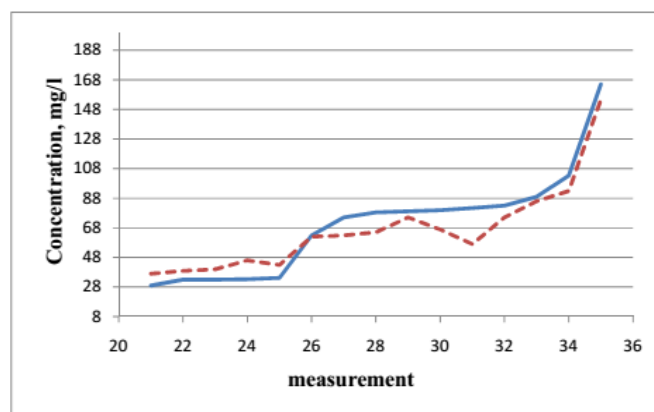
**Table 6.** Measurement errors.

Measurement range, mg/l	Relative error, %	Absolute error, mg/l
1-10	109	1.3
10-100	22	9.5
100-1,000	11	28
1,000-10,000	23	392

At low concentrations, for example in the range from 1 to 10 mg/l, it is not reasonable to estimate accuracy of measurements based on the relative error; it is better to focus on the absolute error.

At the third stage, after the laboratory tests, the automatic gold analyzer was installed directly in the electrolysis barren solution discharge line at Svetlinskaya Gold Mill.

The device measurement results are shown in Figures 4 and 5. Electrolyser discharge solutions were used as low concentration calibration solutions. High concentration calibration solutions were produced by diluting desorption eluates with electrolysis discharge barren solutions.

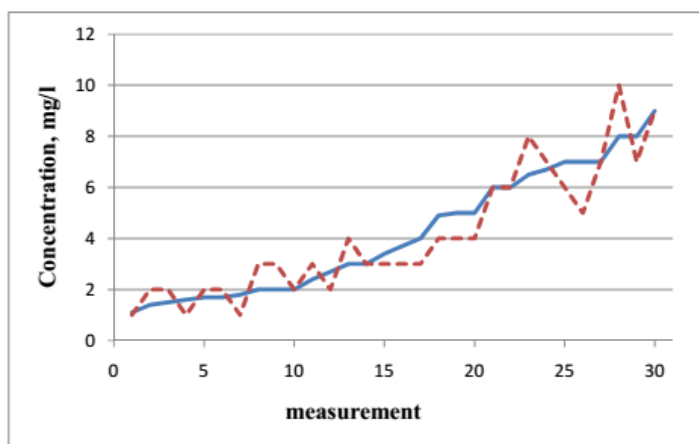


**Figure 4.** Comparative measurement chart. The full line shows the results of atomic absorption measurements, the dashed line shows the results of the device. Results within the range from 10 to 200 mg/l.

Average errors of these measurements are shown in Table 7.

**Table 7.** Measurement errors.

Measurement range, mg/l	Relative error, %	Absolute error, mg/l
1-10	127	3.42
10-100	17.4	9.1
100-1,000	8	10.15



**Figure 5.** Comparative measurement chart. The full line shows the results of atomic absorption measurements, the dashed line shows the results of the device. Results within the range from 1 to 10 mg/l.

Average errors of these measurements are shown in Table 8.

**Table 8.** Measurement errors.

Measurement range, mg/l	Relative error, %	Absolute error, mg/l
1-10	20.3	0.68
10-100	23.4	3.5

## CONCLUSIONS

The testing of the automatic device controlling the concentration of gold in cyanide solutions resulted in the following conclusions:

- The automatic device controlling the gold concentration in cyanide solutions ensures acceptable accuracy as compared to the atomic absorption method.
- The advantages of the device versus the atomic absorption method:
  - Ensures the measurements of gold concentration in cyanide solutions directly in process flows within a wide concentration range;
  - No need in predilution of samples for further measurements;
  - The device can be used in the process automatic control systems at gold mills;
  - Continuous rapid method.

However, there are some remarks as for the gold concentration measurement. At measuring high concentrations (Figure 3d), one can see a measurement error increase; at that, device readings are always lower as compared to the atomic absorption method. The high concentration measurement error is mainly dependent on the error at measuring diluted gold concentrations in the calibration solutions, as well as on concentration measurement by the atomic absorption method when comparing device and laboratory results. The atomic absorption method, depending on the device model, means measurements without sample dilution to 5-10 mg/l. Then, the sample is 100-200 times diluted, which introduces an additional error. Besides, when measuring concentrations from higher to lower, one can see the “fouling” of the device measuring

line. So, to remedy this problem it is recommended to dilute solutions starting from 100 times dilution in order to exclude intrusion of high concentration gold solutions into the spraying system of the device. After gold concentration measurements, solutions can be further diluted 50, 25, 10, 5 times providing maximum concentration 10 mg/l to introduce into the spraying system that ensures a minimum error.

## ACKNOWLEDGMENT

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