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Identification of corrosion of galvanized pipes in the water supply system

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ABSTRACT

The data on the research and application of a new method for identifying corrosion of house water plumbing made of galvanized steel pipes are presented. The method can be used for regular monitoring of the technical condition of cold and hot water supply systems made of galvanized steel pipes in residential, public and industrial buildings. The method is based on determining corrosion products of pipelines and equipment, zinc and copper in particular, on a indicator specimen. The technical result of the proposed solution is the possibility of its application directly from the start of the operation of the water supply system as well as reducing the time to identify the occurrence of corrosion of pipelines and equipment during long-term operation.

Key words: house water plumbing, corrosion, water quality, identification of corrosion, steel pipe, zinc coatings.

The purpose of inspecting the condition of pipelines in drinking water supply systems is to ensure their trouble-free operation and uninterrupted water supply to the customers. In this regard, the main task of technical diagnostics is to identify potentially dangerous sections of pipelines, determine the extent of their damage and develop the necessary measures for carrying out rehabilitation.

Currently, there is a wide variety of methods of diagnostics and monitoring the condition of pipeline systems with different sets of equipment to solve a wide range of problems. For public utilities this is primarily the timely detection of water and heat carrier leaks that arise as a result of external and internal corrosion of pipelines. The causes of corrosion of steel pipelines are described elsewhere [1; 2].

The most widely used methods of monitoring the condition of pipelines are as follows: visual measurement, eddy-current, acoustic-emission, X-ray graphical and thermal imaging control, magnaflux inspection, ultrasonic-based control (thickness gauging, crack detection), ultrasonic

inspection (ultrasound screening), durometric analysis (hardness measurement), video diagnostics (tele-inspection), using sound meters (leak detectors), metal magnetic memory method and non-contact magnetometric inspection [3].

Of the mentioned methods video diagnostics (tele-inspection using telerobots), and recently, a new unique method of non-contact magnetometric inspection of out-door pipelines dominate in practice.

Another control method is based on the use of ultrasound where ultrasonic sensors are placed on the outside of the pipelines to measure pipe wall thickness in places where there is a risk of internal corrosion [5]. The disadvantage of this method is that monitoring the presence of general or pitting corrosion is carried out in a small pipeline section, that is, as a rule, accessible only for the installation of sensors.

However, despite the availability of dozens of control methods and options for their application, these methods are not used for domestic plumbing systems due to known limitations for small pipe diameters and low accessibility of pipelines. In

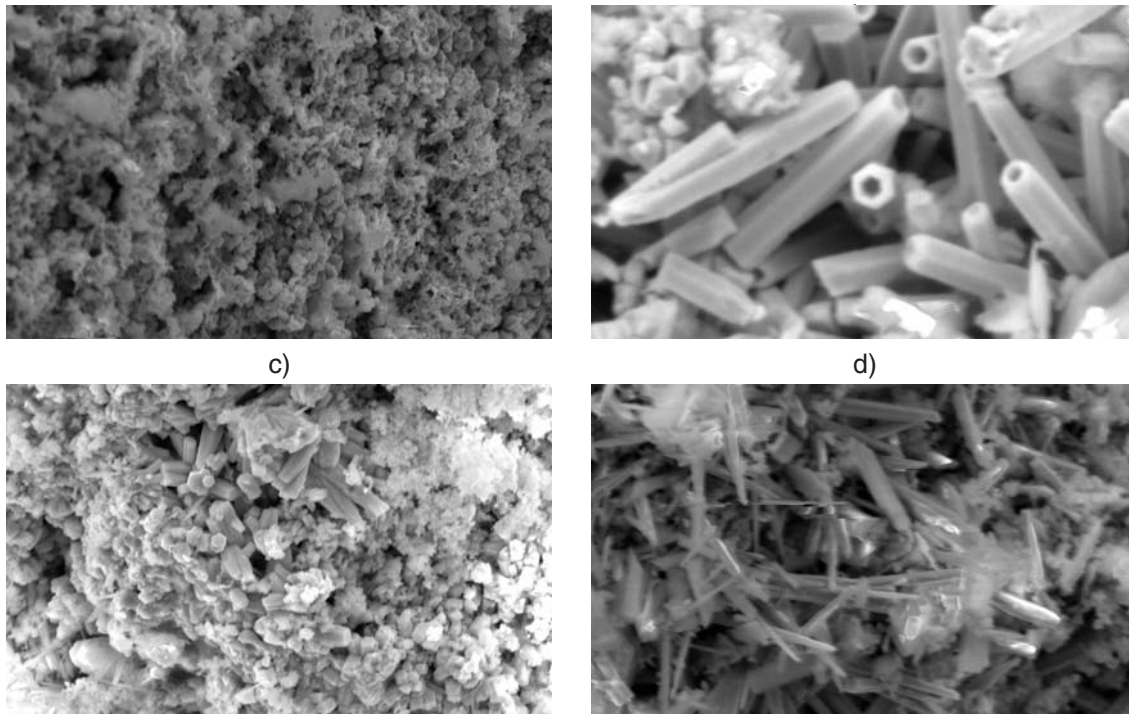
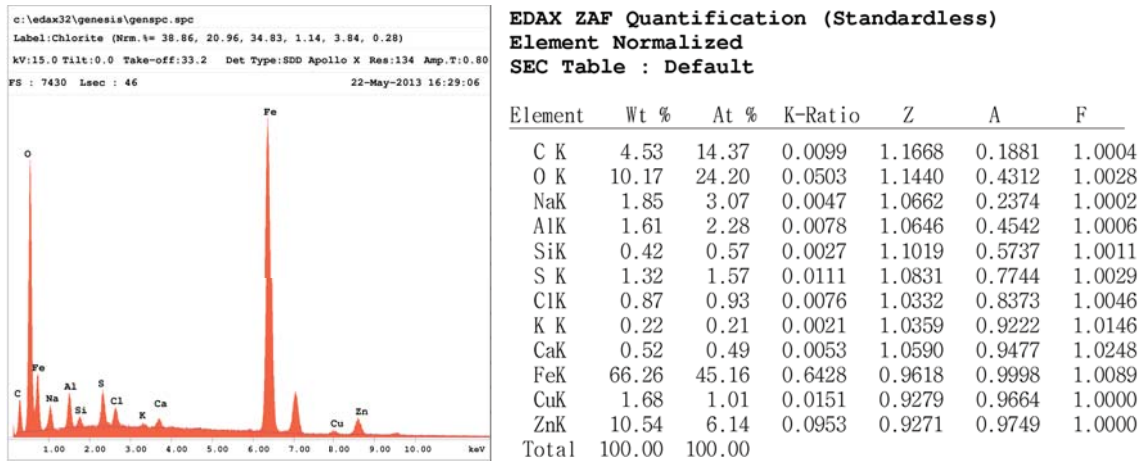


Fig. 1. Spectrogram, chemical composition and micrographs of deposits taken from a pipe of a hot water supply system

a – through damages; *b, c, d* – fragments of the surface of a galvanized pipe with broken zinc coating

practice the simplest way to control the corrosion of pipelines of internal cold and hot water supply systems is to sample water and measure the concentration of elements contained in the pipe material and enter water as a result of corrosion. For steel galvanized pipes such elements are iron and zinc. The disadvantage of this method of determination is a very low increase in the concentration of the measured element in the water sample comparable with the error while measuring the concentration of this element by chemical analysis methods.

The presence of corrosion can also be determined in the process of sampling water after a long break in water consumption. The appearance of rusty water immediately after maintenance work should not be confused with the presence of heavy corrosion.

In accordance with Sanitary Rules and Norms 2.1.4.1074-01 the concentration of iron and zinc in tap water should not exceed 0.3 and 5 mg/l, respectively.

More time-consuming, however, more informative, is a method of corrosion detection that involves installing and regular checking the removable metal corrosion indicators in pipelines and equipment subject to internal corrosion [5; 6]. According to this method the corrosion rate is determined by the weight loss of the indicator specimen. An indicator specimen in the form of plates or pipe sections precleared of corrosion products is placed in a pipeline or in equipment. The disadvantages of the method include a limited applicable scope since it is mainly used to control corrosion of steel pipes without protective

coating. In addition, the method requires a long exposure of the indicator specimen in the inspected pipeline and a long time for its installation and dismantling.

Corrosion of zinc coating of pipes is a natural process and proceeds similarly to corrosion of uncoated steel pipes, however, at a lower rate. At water temperatures up to 50 °C and above 90–95 °C corrosion products have sufficiently high protective properties and form a dense continuous film on the surface. A higher rate of corrosion of zinc in water is observed at temperatures above 55 °C. The maximum is observed at a temperature of 70 °C. Hereupon the destruction of the metal is very slow. The maximum corrosion rate of zinc is explained by the formation of an incoherent film consisting of $Zn(OH)_2$ that does not have good protective properties since it easily peels off. In neutral solutions corrosion of zinc as well as iron takes place with oxygen depolarization. The standard electrochemical potential of zinc is -0.76 V, that of iron -0.44 V. Therefore, in the zinc – iron galvanic pair zinc is the anode and iron is the cathode [7].

In the process of inspecting water supply systems with signs of corrosion [8; 9] with the use of advanced instrumental analysis tools it was found that a large amount of zinc and, in some cases, copper is contained in corrosion deposit. Deposit samples were taken from various sites directly during repair works. Deposits removed from the aerator of the mixer of the hot water supply system of an individual residential building contained zinc in a concentration of about 37% by weight. The cause of corrosion was current leakage due to a malfunctioning electric heater. Figure 1 shows a spectrogram, microphotographs, and chemical composition of the deposits taken at one of the inspected projects from the inner surface of the corroded pipeline.

From the represented data on the elemental composition and micrograph (Fig. 1, *a*) it is evident that the deposits covering the pipe surface contain zinc and have a porous structure that does not interfere with the penetration of oxygen. Therefore, the initiated corrosion will continue until through-holes appear. Zinc detected in the deposits was both in amorphous form and in the form of crystals. Figure 1, *b* shows a photomicrograph of a corroded zinc layer coating of a pipe 100 mm in diameter representing zinc oxide crystals of ZnO . Obviously, this is one of the zinc layers formed during hot galvanizing, namely ζ -phase.

The observational data was taken as a basis ground for the development of a new method for identifying corrosion. Its essence [10] lies in placing a pre-prepared steel indicator specimen in a container

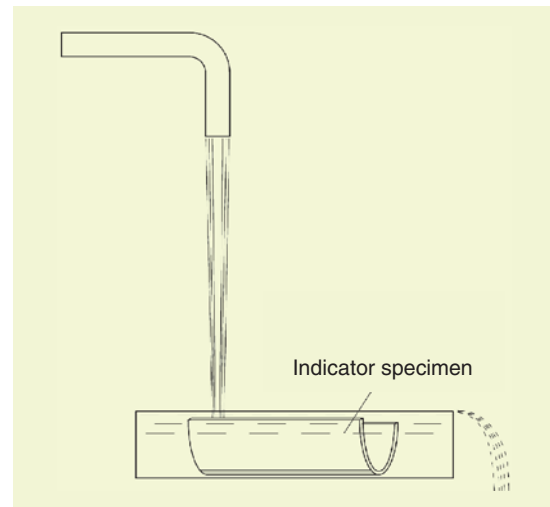


Fig. 2. Design of the experiment

under a stream of cold or hot water in the studied water supply system made of galvanized steel pipes (including copper-containing fittings and heat exchangers); the specimen is kept under the water stream until corrosion products firmly attached to the surface are formed (deposits). After that, the indicator specimen is removed from the container, dried, and the state of the water supply system is determined by measuring the elemental composition of the deposits.

Figure 2 represents a flow scheme that was used for determining the corrosion rate and analyzing the composition of corrosion deposits on the indicator specimen.

To carry out the proposed method, two plates having dimensions of 3×5 cm and an area of 15 cm^2 were cut from a new non-galvanized steel pipe (diameter 40 mm). To remove rust and oxide film that forms on the surface of the pipe in the open air, the specimens were sanded from the inside with sandpaper to a metallic luster.

The prepared indicator specimen was placed in a container under a stream of cold tap water for 2–6 hours with a minimum flow rate of 20–25 l/h to provide for a solid jet. The jet fell from a height of 20–30 cm onto the inner surface of the specimen that was subsequently subject to analysis (Fig. 2). The second specimen was placed under a hot water jet under the same conditions. The container where the indicator specimens were placed should ensure their complete immersion in water and continuous contact with running water. The material of the container should not react with water (glass, ceramics, plastic, etc.).

In the presence of corrosion in the studied pipelines positive zinc and/or copper ions released from the surface of galvanized pipes and heat exchangers precipitate on freshly formed iron oxides in the cathode sections of the indicator specimen.

Table 1

| Measured element | Project No. 1 (Moscow, NAD) | | Project No. 2 (Moscow, EAD) | | Project No. 3 (Mytishchi town) | | Project No. 4 (Moscow, CAD) | |
|-------------------|---|-------|--------------------------------|-------|-----------------------------------|-------|--------------------------------|-------|
| | Wt% | At% | Wt% | At% | Wt% | At% | Wt% | At% |
| C | 6.24 | 13.52 | 3.71 | 11.56 | 4.01 | 9.67 | 9.83 | 19.91 |
| O | 32.94 | 53.57 | 14.19 | 33.17 | 29.31 | 53.08 | 27.71 | 45.18 |
| Na | – | – | – | – | 1.49 | 1.88 | – | – |
| Mg | – | – | – | – | 0.42 | 0.5 | 1.02 | 1.02 |
| Al | – | – | – | – | 0.33 | 0.36 | 0.57 | 0.51 |
| Si | 1.19 | 1.1 | 0.4 | 0.53 | 1.99 | 2.05 | 0.7 | 0.61 |
| S | – | – | 0.11 | 0.13 | – | – | 0.78 | 0.59 |
| Ca | 26.66 | 17.31 | 0.12 | 0.11 | 1.11 | 0.8 | 41.13 | 24.97 |
| Mn | – | – | 0.5 | 0.34 | – | – | – | – |
| Fe | 19.09 | 8.89 | 80.24 | 53.74 | 59 | 30.61 | 9.86 | 4.3 |
| Cu | 7.62 | 3.12 | 0.36 | 0.21 | 0.3 | 0.14 | – | – |
| Zn | 6.27 | 2.49 | 0.38 | 0.22 | 2.03 | 0.9 | 4.83 | 1.8 |
| Conclusion | Heavy corrosion of the pipes and heat exchanger | | No corrosion | | Slight corrosion of the pipes | | Heavy corrosion of the pipes | |

Notes:
1. Wt% – weight percent, At% – atomic percent.
2. Project 1 – an educational institution. Hot water is prepared in an individual heating unit. The network has been in operation since 1983. Water mains are long; they are laid in the basement in parallel with other utility lines.
3. Project 2 – a 5-storied apartment building, in 1998 the pipes were replaced with new ones, almost no basement. Heat supply from the central boiler station of the district that is built-up with similar apartment buildings.
4. Project 3 – a 15-storied apartment building, in operation since 2014; central boiler station. Utility lines in the basement.
5. Project 4 – a 25-storied apartment building, in operation since 2016, central boiler station. Utility lines in the basement.

Table 2

| Measured element | Background values of element concentration on the indicator surface | | Actual values of element concentration on the indicator surface (Project No. 1) | | | |
|-------------------|---|-------|---|-------|-----------------|-------|
| | | | cold water | | hot water | |
| | Wt% | At% | Wt% | At% | Wt% | At% |
| C | 1.55 | 6.52 | 3.02 | 8.35 | 2.61 | 8.75 |
| O | 1.25 | 3.94 | 22.27 | 46.22 | 10.68 | 26.85 |
| Mg | 0.25 | 0.52 | 0.29 | 0.4 | 0.54 | 0.9 |
| Al | 0.45 | 0.85 | 0.3 | 0.37 | 0.29 | 0.44 |
| Si | 0.48 | 0.86 | 0.61 | 0.73 | 1.74 | 2.49 |
| P | 0.2 | 0.33 | 0.24 | 0.25 | 0.11 | 0.14 |
| S | 0.16 | 0.26 | 0.25 | 0.26 | 0.09 | 0.12 |
| Cl | 0.1 | 0.14 | 0.14 | 0.13 | 0.1 | 0.11 |
| K | 0.03 | 0.03 | 0.06 | 0.05 | 0.06 | 0.06 |
| Ca | 0.03 | 0.04 | 0.16 | 0.13 | 1.24 | 1.24 |
| Cr | 0.12 | 0.12 | 0.18 | 0.12 | 0.17 | 0.13 |
| Mn | 0.53 | 0.49 | 0.36 | 0.22 | 0.56 | 0.41 |
| Fe | 94.61 | 85.71 | 70.88 | 42.14 | 76.36 | 54.99 |
| Cu | 0.15 | 0.12 | 0.34 | 0.18 | 1.37 | 0.87 |
| Zn | 0.09 | 0.07 | 0.89 | 0.45 | 4.06 | 2.5 |
| Conclusion | | | Slight corrosion | | Heavy corrosion | |

The effect of sorption of heavy metals and other substances on iron oxides is well known [11]. An increase in the oxygen concentration in the falling water sheet during the contact with the ambient air enhances the corrosion of the specimen. After exposure the specimens were removed from water; the loose deposit was removed under a strong water jet and dried.

The elemental composition of the deposit on the surface of the specimens was determined with a Quanta 250 FEI scanning electron microscope using energy-dispersive X-ray spectroscopy. Then the results were compared with the background values that were determined after the specimen preparation. The conclusion about the corrosion rate was made when the index of zinc and/or copper concentration in the deposit on the surface of the sample was exceeded. Quantitative results of the analysis for the identification of corrosion of galvanized steel pipes in the hot water supply system of the four examined projects using corrosion indicators are given in Table 1.

To reduce the amount of work required to prepare an indicator specimen one and the specimen can be used for time-series identification of the presence of corrosion in cold and hot water supply systems. To this end the specimen is first placed under a cold-water jet, dried and the composition of the deposit is determined. Then the specimen with deposit is placed under a hot water jet, and the corrosion rate is determined, if required. Table. 2 presents the data obtained using a single specimen, – quantitative results on the identification of corrosion of galvanized steel pipes in a system of cold and hot water supply using one and the same corrosion indicator.

The presence of zinc in the deposit in amount of more than 4% (Projects No. 1 and 4) indicates the presence of heavy corrosion, up to 1–2% (Project No. 3) – slight corrosion. The presence of copper indicates corrosion of the water heater having brass tubes. At Project No. 2 the composition of the deposit approximately corresponded to the background values of the concentration of elements in the metal of the indicator specimen; therefore, it was concluded that there was no corrosion.

CONCLUSIONS

1. The proposed method for identifying corrosion can reduce the time required to detect the initial manifestations of intense corrosion of galvanized pipes, reduce the cost of determining the condition of pipes, fittings and water heaters and, as a result, take timely measures to prevent the further development of corrosion processes.

2. The most intense corrosion is observed in buildings with long water plumbing laid in parallel with other utility networks including electric ones. Specific causes of corrosion can only be established by conducting a comprehensive survey of water supply systems.

REFERENCES

1. Ulig G. G., Revi R. U. *Korroziia i bor'ba s nei. Vvedenie v korroziionnuu nauku i tekhniku* [Corrosion and corrosion control. An introduction to Corrosion Science and Engineering. Translated from English. Under the editorship of A. M. Sukhotin. Leningrad, Khimiia Publ., 1989. 456 p.].
2. Akol'zin P. A. *Preduprezhdenie korrozii oborudovaniia tekhnicheskogo vodo- i teplosnabzheniia* [Preventing corrosion of process water and heat supply equipment. Moscow, Metallurgii Publ., 1988. 95 p.].
3. Chistiakova A. V., Orlov V. A., Chukhin V. A. [Diagnostics of the technical condition of metal pipelines]. *Prirodoobustroistvo*, 2016, no. 2, pp. 48–54. (In Russian).
4. Pipeline Corrosion. Final report. Submitted to U. S. Department of Transportation Pipeline and Hazardous Materials Safety Administration Office of Pipeline Safety Integrity Management Program Under Delivery Order DTRS56-02-D-70036, Submitted by Michael Baker Jr., Inc. Contributing Author Raymond R. Fessler, Ph. D. BIZTEK Consulting, Inc. November 2008.
5. Techniques for Monitoring Corrosion and Related Parameters in Field Applications. NACE International. Texas, 1999.
6. Akol'zin P. A., Zhukov A. P. *Kislородnaia korroziia oborudovaniia khimicheskikh proizvodstv* [Oxygen corrosion of chemical processing equipment. Moscow, Khimiia Publ., 1985. 240 p.].
7. Reizin B. L., Strizhevskii I. V., Sazonov R. P. *Zashchita sistem goriachego vodosnabzheniia ot korrozii* [Protection of hot water systems against corrosion. Moscow, Stroizdat Publ., 1986. 112 p.].
8. Chukhin V. A., Andrianov A. P. [Analysis of the causes of corrosion of galvanized pipes in hot water supply systems]. *Santekhnika, Otoplenie, Konditsionirovanie*, 2018, no. 1, pp. 54–58. (In Russian).
9. Andrianov A. P., Chukhin V. A., Smirnovskaia A. M. [Hot water system. Galvanized steel pipe corrosion]. *Tekhnika i Tekhnologii Mira*, 2015, no. 7, pp. 31–36. (In Russian).
10. Chukhin V. A., Andrianov A. P. [Pat. 2666574C1, RF IPC G01N 17/04. Method for identifying corrosion of galvanized steel pipes in water systems]. *Izobreteniia. Poleznye Modeli*, 2018, no. 26. (In Russian).
11. Lubentsova K. I., Pastukhov A. V., Davankov V. A., Kitaeva D. Kh., Karandi I. V., Il'in M. M. [Sorption of toxic organic and inorganic compounds by composites with nanodispersed iron oxides in polystyrene sorbent matrices]. *Sorbtsionnye i Khromatograficheskie Protssy*, 2015, v. 15, is. 3, pp. 333–344. (In Russian).