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# MODERNIZATION OF AUTOMATIC CHEMICAL CONTROL OF TPP POWER UNITS BASED ON CONDUCTIVITY AND PH MEASUREMENTS[1]

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Increasing the volume and tightening the quality standards for the water heat carrier of power units require the modernization of the chemical control system at thermal power plants (TPPs). The development of information technologies ensures the creation of automated systems of chemical-technological monitoring (SCTM) and individual devices focused on the application of reliable and inexpensive analyzers such as conductometers and pH meters with data processing using algorithms of any complexity. SCTM of feed and boiler water based on measurements of specific conductivity and pH were developed and tested under industrial conditions. Together with NPP Tekhnopribor (Moscow), a new generation analyzer Leader-APK, similar to the latest generation analyzer AMI Deltacon Power (SWAN Company), was developed. Using the analyzer in the chemical control system of a power unit of combined cycle gas turbine power plants (CCGT) allows reducing the number of automatic control devices by seven units.

**Keywords:** heat carrier quality standards; automatic chemical control of the water regime; modernization of monitoring systems.

**The state and possibilities of modernization of the water heat carrier chemical control.** In the absence of uniform rules of technical maintenance (the last edition of the RTM was published more than 15 years ago), it is possible to use the regulations developed in VTI [1] and presented as an organization standard in 2009. Water heat carrier quality standards for thermal power plants according to [1] were toughened in comparison with the standards of RTM [2]. Table 1 shows a comparison of the standard quality indicators of feed water for three types of steam boilers. An increase in the chemical control volume, first of all, due to the introduction of additional specific conductivity measurements of a direct or H-cationized sample ($\chi$ or $\chi_H$) of feed water, boiler water and steam, should be noted since this was not the case before. While keeping the volume of pH measurements, a new indicator TOC (Total Organic Carbon) has also been introduced. This approach, as it was noted in paper [1], takes into account the requirement of the national standards of the USA and Germany [3].

The toughening of requirements for the quality of the water-chemical regime (WCR) at TPPs makes it necessary to search for ways to further improve both the water regime and the methods and means of automatic chemical control of it. Along with the hydrazine-ammonia water-chemical regime (HAWR), the amine-based water-chemical regime (ABWR) is increasingly used [1]. Quality standards for water and steam [1] and analyzers for their control are often based on the cooled samples specific conductivity measurements. Such analyzers are the FAM Deltacon pH and AMI Deltacon Power of SWAN Company. The AMI Deltacon Power analyzer provides indirect measurements of the pH hydrogen indicator and ammonia concentration in the feed water of the power unit by the measured values of the specific conductivity of the direct and H-cationized samples.

With an increased measurements volume during automatic chemical control (ACC), which is typical for CCGT power units, and inconsistency of separate indicators, deviations of a number of current values from the standard ones may occur as it is shown in Table 2.

The tendency to maintain the ammonia batching up to 1000 μg/dm$^3$ [1] leads to decreased pH values, and the absence of automatic control and adjustment of phosphate batching leads to a decrease in alkalinity and pH of the boiler water.

The analysis of the state of water heat carrier quality estimation was carried out with the participation of the authors and is given in papers [4, 5].

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**TABLE 1.** Comparison of the Quality Standards of Feed Water for Natural Circulation Boilers, CCGT Waste-Heat Boilers and Direct-Flow Boilers

| Indicator | Standards for | | | | |
|---|---|---|---|---|---|
| | CCGT waste-heat boilers (HAWR) | drum-type boilers with a pressure of 13.8 MPa (HAWR) | | direct-flow boilers with a pressure of 23.0 MPa (OAWR) | |
| | [1] | [2] | [1] | [2] | [1] |
| Total hardness, μg-eq/dm$^3$ | ≤0.2 | ≤1 | ≤0.2 | ≤0.2 | ≤0.2 |
| Content of iron compounds, μg/dm$^3$ | ≤20 | ≤20 | ≤10 | ≤10 | ≤10 |
| Content of copper compounds, μg/dm$^3$ | — | ≤5 | ≤3 | ≤5.0 | ≤2.0 |
| Content of dissolved oxygen, μg/dm$^3$ | ≤10 | ≤10 | ≤10 | 100 – 400 | 50 – 150 |
| pH value | 9.2 – 9.6 | 9.1 ± 0.1 | 9.1 ± 0.1 | 8.0 ± 0.5 | 8.0 ± 0.5 |
| Content of silicic acid, μg/dm$^3$ | ≤20 | ≤60 | ≤10 | ≤15.0 | ≤10 |
| Content of sodium compounds, μg/dm$^3$ | ≤10 | ≤50 | ≤5 | ≤5.0 | ≤5 |
| Specific conductivity of the direct sample, μS/cm | 4.0 – 11.0 | — | 2.8 ± 4.4 | — | ≤1.0 |
| Specific conductivity of the H-cationized sample, μS/cm | ≤0.2 | ≤1.5 | ≤0.3 | ≤0.3 | ≤0.1 |
| Content of hydrazine, μg/dm$^3$ | — | 20 – 60 | 20 – 60 | — | — |
| Content of ammonia, μg/dm$^3$ | ≤1000.0 | ≤1000 | ≤1000 | ≤1000 | ≤500 |
| Content of oil products, mg/dm$^3$ | ≤0.1 | ≤0.3 | ≤0.3 | ≤0.1 | ≤0.1 |
| TOC (Total Organic Carbon), μg/dm$^3$ | ≤100.0 | — | ≤200 | — | ≤100 |
| Content of chlorides, μg/dm$^3$ | ≤3.0 | — | — | — | ≤3 |

**Note.** HAWR is the hydrazine-ammonia water-chemical regime; OAWR is the oxygen-ammonia water-chemical regime.

**TABLE 2.** Operational Data on Maintaining the Water-Chemical Regime of the CCGT-410T Power Unit of Novo-Salavatskaya CHPP LLC (01.03.2017 – 31.03.2017)

| Quality indicator | Standard | Analysis results | | |
|---|---|---|---|---|
| | | minimum | maximum | average value |
| **Low pressure feed wate** | | | | |
| $pH_{aut}$ | 9.2 – 9.6 | 8.94 | 9.43 | 9.28 |
| Total hardness, μg-eq/dm$^3$ | — | 5.00 | 9.00 | 6.25 |
| Content of silicic acid, μg/dm$^3$ | — | 5.00 | 9.00 | 6.25 |
| Content of ammonia, μg/dm$^3$ | 1000.0 | 300.00 | 1038.00 | 640.47 |
| Content of sodium, μg/dm$^3$ | 10.0 | 0.00 | 2.60 | 0.91 |
| Specific conductivity of the H-cationized sample, μS/cm | 0.2 | 0.09 | 0.26 | 0.13 |
| Specific conductivity, μS/cm | 6.00 | 4.58 | 8.65 | 5.93 |
| Content of hydrazine, μg/dm$^3$ | 20 – 60 | 20.00 | 48.50 | 29.59 |
| Content of iron compounds, μg/dm$^3$ | 20.0 | 3.00 | 197.00 | 29.57 |
| **Medium pressure boiler water** | | | | |
| $pH_{aut}$ | 9.3 – 9.6 | 7.90 | 9.85 | 9.48 |
| Phosphates excess, mg/dm$^3$ | 2.5 – 5.0 | 1.70 | 4.90 | 2.77 |
| Content of silicic acid, μg/dm$^3$ | 600 | 218.0 | 655.0 | 442.4 |
| Phenolphthalein alkalinity $A_{pp}$, μg-eq/dm$^3$ | 45 – 80 | 0.00 | 63.00 | 40.67 |
| Total alkalinity $A_t$, μg-eq/dm$^3$ | 75 – 120 | 32.00 | 124.00 | 92.47 |
| $A_{pp}/A_t$ ratio | ≥ 0.5 | 0.00 | 0.54 | 0.40 |
| Specific conductivity, μS/cm | 10 – 30 | 6.86 | 28.00 | 20.41 |
| Content of iron compounds, μg/dm$^3$ | 40 | 21.0 | 925.0 | 211.1 |

Improvement of the system of chemical and technological monitoring (SCTM) of boilers and power units based on the automatic chemical control can be carried out in two directions.

1. On the basis of traditional automatic analyzers given in Table 3 according to [1], when capturing, processing and presenting the results in the information system of the boiler (unit). Based on this principle, the authors have developed an SCTM based on conductivity and pH measurements and implemented it on an industrial boiler [6, 7].

Some measurement and calculation results for samples of feed water from drum-type boilers, CCGT waste-heat

**TABLE 3.** Recommended Devices for Automatic Continuous Monitoring [1]

| Monitored indicator | Analyzer device | Measurement range | Error of measuring instrument, % |
|---|---|---|---|
| Specific conductivity, μS/cm | Conductometer with H-filter | 0.0 – 0.5 | ±2.5 |
| | | 0.0 – 5.0 | ±10.0 |
| | | 0.0 – 50 | ±10.0 |
| | | 0.0 – 500 | ±10.0 |
| Sodium compounds (in terms of Na), μg/dm$^3$ | Automatic sodium meter | 0.1 – 100 | ±7.5 |
| pH value | pH meter | 5.00 – 10.00 | ±0.05 pH |
| Content of oxygen, μg/dm$^3$ | Oxygen meter | 0.0 – 1000.0 | ±10.0 |
| Content of total organic carbon, μg/dm$^3$ | ATOS analyzer | 0.0 – 1000.0 | ±2.5 |

**TABLE 4.** Measurement and Calculation of Impurity Concentrations in Feed Water and Steam of Power Boilers

| TPP, boiler | Measured parameters | | | | Calculated parameters | | |
|---|---|---|---|---|---|---|---|
| | $\chi^{25}$, μS/cm | $\chi_H^{25}$, μS/cm | pH$^{25}$ | [NH$_3$], μg/dm$^3$ | [Cl$^-$]$^{conv}$, μg/dm$^3$ | [Na$^+$]$^{conv}$, μg/dm$^3$ | [NH$_3$], μg/dm$^3$ |
| North-West CHPP (St. Petersburg), P-90 | 8.01 | 0.18 | 9.47 | — | 10.3 | 6.77 | 1260.5 |
| | 8.04 | 0.19 | 9.47 | 1400 | 10.9 | 7.15 | 1270 |
| Gusinoozersk SDPP, unit No. 2 | 4.05 | 0.4 | 9.1 | 486 | 22.9 | 15.49 | 450 |
| | 3.22 | 0.45 | 9.1 | — | 25.8 | 17.54 | 326 |
| Saransk CHPP-2, unit No. 2 | 5.42 | 0.9 | 9.2 | 700 | 51.5 | 37.18 | 698.04 |
| | 3.97 | 0.9 | 8.9 | 500 | 51.5 | 37.17 | 446 |
| CHPP-26 Mosénergo, unit No. 1, TGME-96B | 6.64 | 0.92 | 9.42 | — | 52.7 | 38.10 | 950.11 |
| | 4.44 | 0.72 | 9.13 | — | 41.2 | 29.07 | 517.76 |
| Konakovo SDPP, unit No. 6 | 0.195 | 0.183 | 7.64 | — | 10.5 | 6.39 | 12.07 |
| | 0.196 | 0.187 | 7.62 | — | 10.7 | 6.54 | 12.13 |
| Perm SDPP, unit No. 1, 2 | 0.28 | 0.08 | 7.99 | — | 4.6 | 2.72 | 17.91 |
| | 0.27 | 0.09 | 7.99 | — | 5.2 | 3.09 | 17.21 |

**Note.** The calculated values of [Cl$^-$]$^{conv}$ are determined by the sum of strong acid anions in terms of chlorides, and [Na$^+$]$^{conv}$ calculated values are determined by the sum of metal cations in the heat carrier sample.

boilers and direct-flow boilers are given in Table 4. Under the conditions of industrial operation, the measurements volume (Table 4) in the feed and boiler waters is carried out in the normal operation mode.

2. To improve the SCTM, new generation automatic analyzers have been created, which combine the functions of measuring specific conductivity, in particular, and the calculation of such standardized and diagnostic indicators as pH and ammonia concentration for feed water and steam condensate, and the calculation of salinity and phosphates concentration for boiler water. Analyzers of the West European company SWAN are built on this principle; the production of the Russian analyzer Leader-APK by NPP "Tekhnopribor" (Moscow) has been also mastered [8].

Industrial research of SCTM modernization in the first direction was carried out at Ivanovo CHPP-3. Short-term (one-time) measurements were carried out at CHPP-26 Mosenergo, Perm and Konakovo SDPP and others.

Based on the research results, the options for the volume of automatic chemical control of the boilers heat carriers quality were tested to obtain operational information from the system of chemical and technological monitoring of the water-chemical regime state of the super high pressure drum-type boiler ($P_d$ = 13.8 MPa).

Industrial tests were carried out during one heating season, followed by monitoring for several years. Figure 1 shows the results of automatic chemical control of the boiler water quality in the clean and salt compartments of the drum-type boiler TP-87 (station No. 3) of Ivanovo CHPP-3.

The SCTM software calculates the values of the concentrations of ammonia in feed water and phosphates in boiler water on the base of the measured instrumental data. The data of the tests showed a fairly good convergence of the results of calculated and laboratory measurements (chemical laboratory of Ivanovo CHPP-3).

The data obtained during selective control can be used to assess the WCR state using the state diagram of phosphate water-chemical regimes.

An example of the SCTM modernization in the second direction is the Leader-APK analyzer (Fig. 2), which implements a new method for the indirect determination of pH, concentrations of ammonia, chlorides, sodium (conventional) based on measurements of the specific conductivity of cooled samples of feed water and steam: direct ($\chi$) and H-cationized ($\chi_H$) [8, 9].

The Leader-APK analyzer can be used on TPP units, including CCGT power units, to control the quality of make-up (deep desalinated) water, feed water and steam condensate.

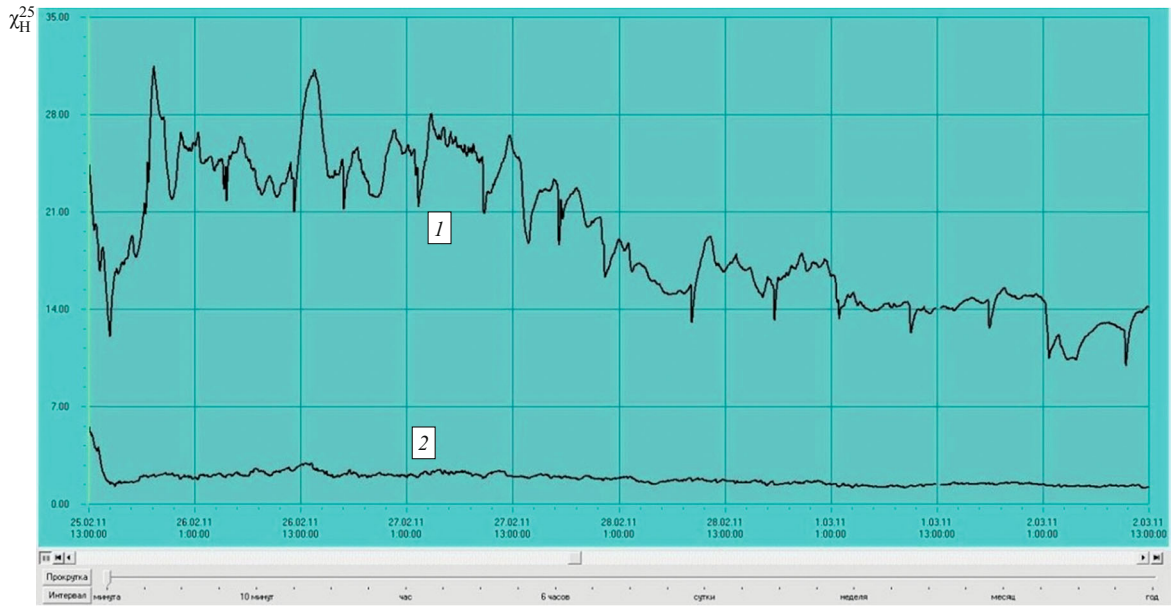


**Fig. 1.** Automatic registration of the specific conductivity of the cooled H-cationized sample of the water heat carrier of the boiler No. 3 of Ivanovo CHPP-3: *1*, boiler water (salt compartment); *2*, boiler water (clean compartment).

Industrial tests of a prototype of the automatic analyzer Leader-APK at Petrozavodsk CHPP and Kostroma SDPP (Table 5) showed high performance of the device for indirect pH measurements with an error within the passport error of an industrial pH meter (±0.05 pH units), indirect measurements of the ammonia concentration in condensate-type waters with an error within 5%, indirect measurements of the chloride ions concentration and the total concentration of hardness and sodium cations in terms of sodium without evaluating the measurement accuracy.

In 2017, the Leader-APK analyzer was presented at the World Innovation Salon in Geneva (Switzerland), where it was awarded a gold medal.

A measuring system based on cooled samples conductivity measurements, as well as on the solution of mathematical models of ion equilibria in feed water and steam of direct-flow boilers, can be used to estimate the concentration of potentially acidic organic matters (PAM) in feed water. The use of conductivity and pH measurements in boilers with supercritical pressure (SCP) for this purpose is known from the literature [10, 11]. The solution of such a problem is especially important for boilers with oversupercritical parameters (OSCP), due to the increase in the residence time of water and steam at high temperatures (up to 600 °C). In this case, the measurement of the content of organic matters is identical to the measurement of total organic carbon by the TOC analyzer (Fig. 3).

The method is distinguished by its implementation simplicity, the use of standard measurements of the conductivity of feed water and steam, as well as by featuring the corrosive and hazardous matters of an acidic nature from all organic degradation products.

Using the measured difference in conductivities of H-cationized samples of superheated steam and feed water

**TABLE 5.** Measurement Data of the TPP Automatic Chemical Control System and the Leader-APK Prototype during Quality Control of Feed and Desalinated Make-up Water

| Object | Item No. | TPP monitoring system | | | | Leader-APK | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\chi$, μS/cm | $\chi_H$, μS/cm | pH | $[NH_3]$, μg/dm³ | $\chi$, ìS/cm | $\chi_H$, μS/cm | pH | $[NH_3]$, μg/dm³ | $Na^{conv}$, μg/dm³ | $[Cl^-]$, μg/dm³ |
| Petrozavodsk CHPP | 1 | 4.07 | 0.205 | 9.11 | 501 | 4.09 | 0.222 | 9.17 | 492 | 8.4 | 12 |
| | 2 | 4.10 | 0.144 | 9.15 | 495 | 4.13 | 0.238 | 9.17 | 499 | 9.0 | 13 |
| | 3 | 3.81 | 0.150 | 9.11 | 451 | 3.82 | 0.256 | 9.14 | 445 | 9.7 | 14 |
| | 4 | 0.559 | — | 8.28 | — | 0.557 | 0.134 | 8.31 | — | 57 | 8 |
| Kostroma SDPP | 5 | 0.692 | 0.106 | 8.00 | 81 | 0.689 | 0.183 | 7.98 | 50 | 6.8 | 10 |
| | 6 | 0.702 | 0.105 | 7.98 | 83 | 0.696 | 0.163 | 8.00 | 51 | 6.0 | 9 |
| | 7 | 0.698 | 0.102 | 7.97 | 83 | 0.692 | 0.161 | 8.00 | 50 | 5.6 | 8 |
| | 8 | 0.220 | — | 6.51 | — | 0.218 | 0.388 | 6.55 | — | 32 | 33 |

**Note.** Feed water in Items No. 1 – 3, 5 – 7, desalinated make-up water in Items No. 4, 8.

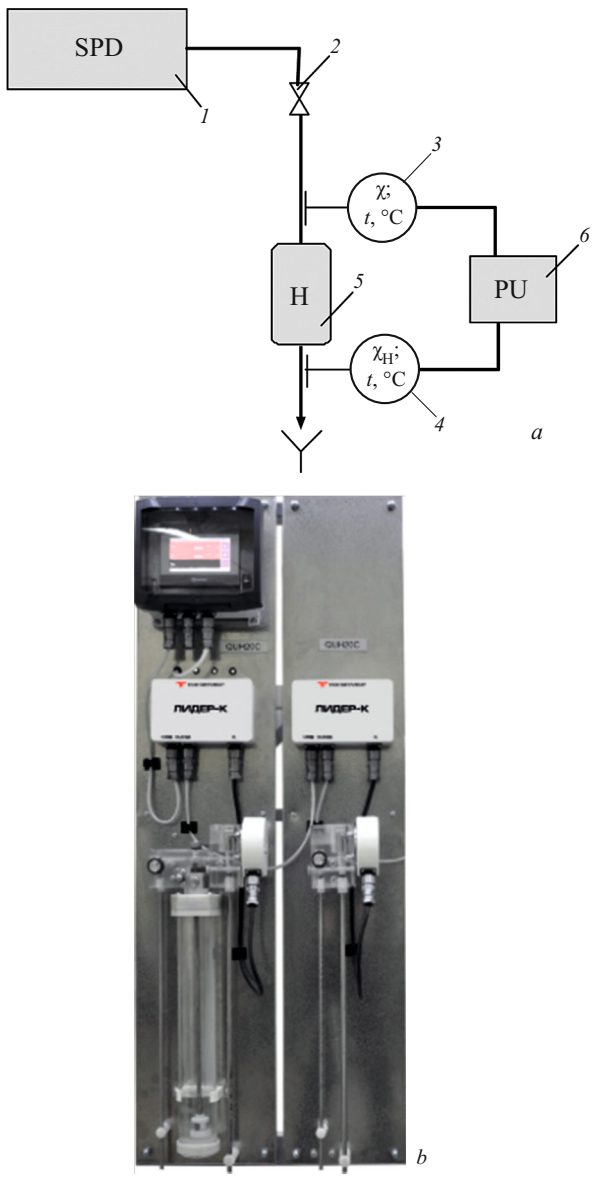


**Fig. 2.** Schematic diagram (*a*) and layout (*b*) of the Leader-APK impurities analyzer: *1*, sample preparation device (SPD); *2*, control valve; *3*, *4*, specific conductivity sensors; *5*, H-cationite column; *6*, data processing and output unit.

($\chi_H^{ss} - \chi_H^{fw}$, μS/cm), one can propose a simple formula for calculating the concentration of organic thermolysis acidic products in terms of acetic acid ($C_{aa}$, μmol/dm$^3$):

$$C_{aa} = 1000 \frac{\chi_H^{ss} - \chi_H^{fw}}{\lambda_{H^+} + \lambda_{CH_3COO^-}}$$

or in μg/dm$^3$

$$C_{CH_3COOH} = 153.5(\chi_H^{ss} - \chi_H^{fw}).$$

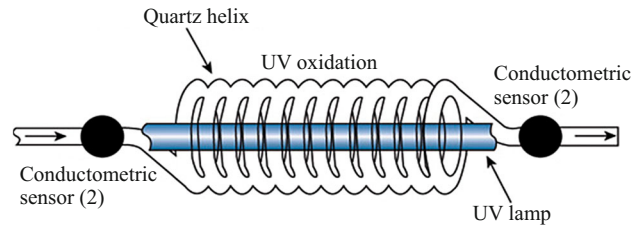


**Fig. 3.** Schematic diagram of the analyzer of total organic carbon in the flow of water heat carrier.

The proposed method was tested on SCP power units with direct-flow boilers (Table 6). The study shows the possibility of using the conductivity (and pH) measurements for the operational quantitative control of the feed water quality of the SCP and OSCP power units by organic impurities, i.e., potentially acidic matters.

The presented method received a patent for an invention [12]. The main results of the research and pre-production prototypes were presented at Russian and international conferences [13].

Procurement of CCGT power unit with ACC devices using new technologies. Massive commissioning of CCGT power units at TPPs in Russia has been observed over the past 15 years. As a rule, the design WCR is ammonia-hydrazine in the feed path, with the dosage of phosphates or alkali into the boiler water. In operating conditions, HAWR is rather often replaced with ABWR with a dosage of complex reagents based on organic amines. The chemical control volume and water heat carrier quality standards are most often determined by the equipment supplier and approved by the TPP technical management.

In the context of SCTM modernization, one should focus, firstly, on the STO standards [1] and, secondly, take into account the possibilities of increasing the ACC information content, which were described above. As an example, the existing ACC configuration of the 399.6 MW CCGT power unit is considered (Table 7). The ACC change (modernization) in accordance with the recommendations of [1] (Table 8) and in the conditions of using an automatic analyzer of the Leader-APK type (Table 9) is also considered.

Table 7 shows the volume and frequency of chemical control: laboratory (LCC) and automatic (ACC) control of the operating three-circuit (HP, MP, LP) 399.6 MW CCGT power unit. Taking into account the requirements of the standard [1], the ACC volume should be supplemented with several measurements of specific conductivity, which is shown in Table 8.

Thus, the number of automatic chemical control devices (excluding oxygen meter) should be increased from 24 to 28 per unit. When processing the readings of the devices in the unit information network, it becomes possible to calculate the concentration of ammonia and chlorides in the feed water, as well as the concentration of phosphates and alkalinity of the boiler water (HP, MP, LP), which makes it possible to diagnose the state of water-chemical regime and to adjust the

**TABLE 6.** Specific Conductivity and pH Values of Feed Water, Steam and Their Difference; the Results of Calculating the Acetic Acid Concentration of the 800-MW Power Unit of Ryazan SDPP

| Date of measurement | | $pH_{fw}^{25}$ | $\chi_{fw}^{25}$, μS/cm | $pH_{ss}^{25}$ | $\chi_{ss}^{25}$, μS/cm | $(\chi_{fw}^{25} - \chi_{ss}^{25})$, μS/cm | $(pH_{fw}^{25} - pH_{ss}^{25})$ | $C_{CH_3COOH_3}$, μg/dm$^3$ |
|---|---|---|---|---|---|---|---|---|
| 5.08.2014 | 07:00 | 6.7 | 0.19 | 6.6 | 0.27 | –0.08 | +0.1 | 12.288 |
| | 09:00 | 6.75 | 0.14 | 6.65 | 0.20 | –0.06 | +0.1 | 9.216 |
| | 14:00 | 6.85 | 0.12 | 6.65 | 0.16 | –0.04 | +0.2 | 6.144 |
| | 18:00 | 6.85 | 0.12 | 6.7 | 0.15 | –0.03 | +0.15 | 4.617 |
| | 22:00 | 6.85 | 0.11 | 6.8 | 0.15 | –0.04 | +0.05 | 6.144 |
| 6.08.2014 | 02:00 | 6.9 | 0.11 | 6.8 | 0.13 | –0.02 | +0.1 | 3.072 |
| | 06:00 | 6.9 | 0.1 | 6.8 | 0.12 | –0.01 | +0.1 | 1.536 |

**Notes.** 1. Power unit No. 6 was put into operation at 05:00 on August 5. 2. fw, feed water; ss, superheated steam.

**TABLE 7.** Volume and Frequency of Operational Chemical Control of a 399.6 MW CCGT Power Unit in Operation Mode

| Sampling point | Controlled indicator | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LCC | | | | | | ACC | | | | |
| | $H_t$ | pH | Fe | $SiO_2$ | $A_t$ | $PO_4^{3-}$ | χ | $\chi_H$ | $[Na^+]$ | $O_2$ | pH |
| Full-flow condensate | 3/shift | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | — | Aut. | Aut. |
| Feed water behind CGH | 3/shift | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | Aut. | Aut. | Aut. |
| Boiler water of HP circuit | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | Aut. | — | — | — | Aut. |
| Boiler water of MP circuit | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | Aut. | — | — | — | Aut. |
| Boiler water of LP circuit | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | 3/shift | Aut. | — | — | — | Aut. |
| HP saturated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | Aut. | — | Aut. |
| MP saturated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | — | — | — |
| LP saturated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | — | — | — |
| HP superheated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | Aut. | — | Aut. |
| MP superheated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | — | — | — |
| LP superheated steam | — | 3/shift | 3/shift | 3/shift | — | — | — | Aut. | — | — | — |
| Chemically desalinated water | 1/shift | 1/shift | 1/shift | 1/shift | — | — | Aut. | — | Aut. | — | Aut. |

**Notes.** 1. $N_2H_4$ and $NH_3$ are measured in feed water behind CGH with a frequency of 1 time per shift. 2. HP, high pressure; MP, medium pressure; LP, low pressure. 3. 1/shift and 3/shift are the frequencies of indicators measurement, i.e., once and three times per shift, respectively.

**TABLE 8.** ACC Volume of the 399.6 MW CCGT Unit in Accordance with the Standards of [1]

| Sampling point | Controlled indicator | | | | |
|---|---|---|---|---|---|
| | χ | $\chi_H$ | $[Na^+]$ | $O_2$ | pH |
| Full-flow condensate | — | Aut. | — | Aut. | Aut. |
| Feed water behind CGH | Aut. | Aut. | Aut. | Aut. | Aut. |
| Boiler water of HP circuit | Aut. | Aut. | — | — | Aut. |
| Boiler water of MP circuit | Aut. | Aut. | — | — | Aut. |
| Boiler water of LP circuit | Aut. | Aut. | — | — | Aut. |
| HP saturated steam | — | Aut. | Aut. | — | Aut. |
| MP saturated steam | — | Aut. | — | — | — |
| LP saturated steam | — | Aut. | — | — | — |
| HP superheated steam | — | Aut. | Aut. | — | Aut. |
| MP superheated steam | — | Aut. | — | — | — |
| LP superheated steam | — | Aut. | — | — | — |
| Chemically desalinated water | Aut. | — | Aut. | — | Aut. |

dosage of ammonia into feed water and trisodium phosphate solution into boiler water.

In case of using a new generation analyzer of the Leader-APK type, the number of automatic chemical control devices can be reduced from 28 according to Table 8 (excluding the oxygen meter) to 17, with the addition of four Leader-APK analyzers per unit. In this case, the load on the sampling lines (especially for feed water) decreases, a possibility of direct influence on the control of dosage into the circuit of working ammonia solutions appears, and the reliabil-

ity of the SCTM operation in case of failures in the power unit information network increases. The automatic chemical control volume is given in Table 9.

As an example, the results of measurements (Table 10) and calculation (Table 11) according to the methodology proposed by the authors are given for a number of indicators of the water heat carrier quality of the mentioned 399.6 MW CCGT unit.

The results of calculating the quality indicators of water and steam from the measured values of $\chi$, $\chi_H$, and pH according to the proposed calculation method are given in Table 11.

When comparing the data in Tables 10 and 11, it should be taken into account that in instrumental measurements of specific conductivity and pH, the alkalinity indicator measurements were carried out by laboratory chemical control methods and are actually averaged over a certain period of time. The calculated concentration value $[Na^+]^{conv}$ is the sum

**TABLE 9.** ACC Volume of the 399.6 MW CCGT Unit in Case of Using a New Generation Analyzer of the Leader-APK Type

| Sampling point | Controlled indicator | | | | |
|---|---|---|---|---|---|
| | $\chi$ | $\chi_H$ | $[Na^+]$ | pH | Leader-APK |
| Full-flow condensate | — | Aut. | — | Aut. | – |
| Feed water behind CGH | — | — | Aut. | — | |
| Boiler water of HP circuit | Aut. | Aut. | — | Aut. | – |
| Boiler water of MP circuit | Aut. | Aut. | — | Aut. | – |
| Boiler water of LP circuit | Aut. | Aut. | — | Aut. | – |
| HP saturated steam | — | — | — | — | |
| MP saturated steam | — | Aut. | — | — | — |
| LP saturated steam | — | Aut. | — | — | — |
| HP superheated steam | — | — | Aut. | — | |
| MP superheated steam | — | Aut. | — | — | — |
| LP superheated steam | — | Aut. | — | — | — |
| Chemically desalinated water | — | — | — | — | |

**TABLE 10.** Quality Indicators of Condensate, Feed and Boiler Water of the HP, MP, LP Circuits, Saturated and Superheated Steam of the CCGT-425T Unit of Minsk CHPP-5 (According to the Data of Chemical Service)

| Indicator | Sampling place | | | | | | |
|---|---|---|---|---|---|---|---|
| | FC | FW | $BW_{HP}$ | $BW_{MP}$ | $BW_{LP}$ | $SatS_{MP}$ | $SS_{MP}$ |
| Total hardness, μg-eq/dm$^3$ | 0.2 | 0.2 | 0.2 | 0.5 | 0.5 | — | — |
| Content of iron, μg-eq/dm$^3$ | 4 | 4 | 25 | 2 | 154 | 2 | 2 |
| Alkalinity, μg-eq/dm$^3$: | | | | | | | |
| phenolphthalein | — | — | 54 | 76 | 74 | — | — |
| total | — | — | 84 | 104 | 100 | — | — |
| Sodium ion concentration, μg/dm$^3$ | 1.3 | 1.3 | 1090 | 1920 | 2280 | 1.3 | 1.3 |
| Oxygen ion concentration, μg/dm$^3$ | 18 | 10 | 9 | 7 | 6 | 5 | 4 |
| Specific conductivity, μS/shift: | | | | | | | |
| direct sample | 9.02 | 9.20 | 12.5 | 22.3 | 21.1 | 10.3 | 9.61 |
| H-cationized | 0.2 | 0.3 | 0.58 | 0.55 | 1.7 | 0.34 | 0.20 |
| pH value | 9.45 | 9.52 | 9.57 | 9.91 | 9.90 | 9.48 | 9.4 |

**Note.** FC, full-flow condensate; FW, feed water; BW, boiler water; SatS, saturated steam; SS, superheated steam.

**TABLE 11.** Results of Calculating the Quality Indicators of the Water Heat Carrier of 399.6 MW CCGT Unit of Minsk CHPP-5 According to Table 10

| Indicator | Sampling place | | | | | | |
|---|---|---|---|---|---|---|---|
| | FC | FW | $BW_{HP}$ | $BW_{MP}$ | $BW_{LP}$ | $SaS_{MP}$ | $SS_{MP}$ |
| Ammonia, μg/dm$^3$ | 1550 | 1600 | 76.4 | 151 | 148 | 1927 | 1722 |
| $[Cl^-]^{conv}$, μg/dm$^3$ | 11.5 | 17.2 | 48.3 | 46 | 142 | 19.5 | 11.5 |
| $[Na^+]^{conv}$, μg/dm$^3$ | 8.2 | 12.0 | 1322 | 2396 | 2107 | 14.5 | 8.2 |
| Alkalinity, μg-eq/dm$^3$: | | | | | | | |
| phenolphthalein | — | — | 41 | 81 | 80 | — | — |
| total | 33 | 34 | 68 | 100 | 86 | 38 | 35 |

of cations, including hardness cations, and $[Cl^-]^{conv}$ is the total concentration of strong acid anions. Ammonia concentration measurements were carried out sporadically, and during the data collection period the ammonia concentration in the feed water was 1500 μg/dm$^3$.

## CONCLUSION

Bringing the automatic chemical control volume of steam boilers and power units in accordance with the standards of [1] makes it possible to replace a number of automatic and laboratory measurements with one new generation analyzer of the Leader-APK type and obtain additional information about the state of the water-chemical regime by calculating some standard and diagnostic indicators within the framework of the systems of chemical-technological monitoring.

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