Problem of maintaining a normal condensate dissolved oxygen concentration

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Abstract. Study presents the results of the steam surface KCS-200-2 reconstruction. In order to maintain the dissolved oxygen concentration, according to the Code of Operation for Power Plants, the steam sparger was installed in condenser hotwell. Despite the abnormal air leakage level, reducing of dissolved oxygen concentration was reached. The dissolved oxygen concentration reduced, on average, by 2 times. As it was expected, in the cases of low inlet cooling water temperature, the final oxygen concentration did not reach the normal level. In last 3 tests the dissolved oxygen concentration was reduced to 19 mg/l. The results show a possibility of described reconstruction experience.

1. Introduction
The most important duty in the operation of steam turbines of thermal and nuclear power plants is to prevent corrosion of the entire feed-water circuit. Obviously, this is possible only if the water-chemical regime is maintained.

The presence of corrosive gases, such as oxygen and carbon dioxide in the main condensate of the turbine contributes to the intensification of corrosion of pipelines and equipment of the regenerative feedheating system in the condenser-deaerator section. Long work of the steam turbine during excess of dissolved oxygen concentration in feedwater systems has critical impact on the power plant reliability. The financial consequences of high dissolved oxygen concentration could be estimated as the increased repair costs. Figure 1 shows the dependence of the dissolved oxygen concentration on the rate of steel corrosion. It is linear; therefore, with an increase in dissolved oxygen concentration, the number of accidents caused by corrosion damage increases [1].

As the practice of operation shows, several factors have a significant impact on the quality of deaeration, which depend on the operating mode of the turbine and the circulation system.
2 Problem description

According to [2], both condensing and heating turbines face a problem of excess concentrations of dissolved oxygen measured at the outlet of condensate pumps relative to the values established by the rules of technical operation of electric stations and networks [3].

One of the main factors determining oxygen concentration in the turbine condensate is the steam load of the condenser (condenser duty), which depends on the operating mode of the steam turbine. According to [4], deep deaeration of the exhaust steam condensate in the turbine condenser is possible in a wide range of loads. However, when the steam loads of the condenser are below 60-40% of the nominal, there is deterioration in the deaeration regime and an increase in the concentration of dissolved oxygen. This can be explained by the fact that with a decrease in the steam load of the condenser, the zone of mass condensation of steam shifts closer to the exhaust hood, and the cooling zone of the steam-air mixture begins to grow rapidly and go beyond the area of the air cooler. This problem is especially acute for heating turbines that operate for a long time according to a thermal schedule with a minimal steam flow into the condenser.

Separately, it is worth noting the influence of the air leakages on the oxygen content in the main condensate. All air leakages into the steam space of the condenser do not affect the deaeration regime in the condenser, since they are under the influence of the ejector and all the air is removed by the ejector (during normal operation of the ejector) [4]. On the other hand, the closer the air leakage is to the hotwell, the greater the effect it has on aeration of the condensate flowing down from the tubes. The critical moment is the presence of air-leakage in the water volume of the condenser. In this case, all the incoming air cannot be removed by the ejector and is completely mixed with the condensate, saturating it.

Also, the deaerating ability of the condenser is affected by the temperature of the cooling water. It was noted in [4] that for regenerative condensers, the deaeration ability does not decrease even with a decrease in the temperature of the cooling water. However, [5] shows the negative effect of the cooling water temperature lowering on the water-chemical regime of the condensers of the modern steam turbines. The deterioration of deaeration was observed when the temperature of the cooling water at the inlet to the condenser was below 11°C.

Dissolved oxygen produced by sub-cooling in the condenser tube bundle, not heated by steam entering from the bottom of the bundle, will enter the hotwell and will be diluted by condensate, which is not sub-cooled and aerated. Once this saturated with oxygen condensate falls below the bottom of the tube bundle and comes through the liquid surface of the hotwell, the dissolved gases most likely will...
not be released primarily due to the head pressure of water from above. Therefore, it contributes to the increasing of dissolved oxygen concentration in the condensate.

The above analysis indicates that it is impossible to provide the necessary concentration of dissolved oxygen in the main condensate in the condenser-deaerator section for steam turbines. There remains the necessity of special additional measures to intensify desorption of dissolved oxygen in the steam turbine condenser.

3. Actual situation

The process of vapor condensation in the condenser tube bundle is accompanied by mass transfer between non-condensable gases (air) in the vapor and the liquid phase (condensate).

Experience shows that in regenerative condensers, the condensate at the outlet has low concentrations of dissolved oxygen. Thus, the condenser is the first deaeration stage.

Inside the condensers, it is possible to deaerate the condensate directly on the surface of the tubes. In this case, the final concentration of dissolved oxygen depends on the concentration of air in the steam, the steam flow rate, the flow paths of steam and water, and the temperature of cooling water and condensate.

However, to ensure the required quality of deaeration, especially at start-up modes, it is necessary to install a special device.

Various models of steam turbine condenser have installed deaerating devices inside the hotwell. In the designs of condensers for the Soviet and foreign turbines, this solution has been used for more than 60 years. Depending on the flow path of the condensate and the heating fluid, deaeration devices of the condensers are classified as follows: film-type, nozzle-type, jet-type (when water moves in steam), and bubbling-type (when steam moves in water).

Similar devices are used on K-500-60/1500 HTGZ (Fig. 2), K-300-240 LMZ and T-175/210-130 UTZ, and many others turbines. As the thermal tests have shown, these devices allow maintaining the required concentration of the dissolved oxygen in the main condensate in the most operating regimes of the steam turbine.

![Deaerating device of the K-22550 HTGZ surface condenser. 1-tube bundle, 2-air cooler, 3-water distributing sheet, 4-uncooled tubes, 5-non-condensable vent, 6-water collecting sheet.](image)

However, some of the most numerous turbines, such as K-210-130, do not have special deaeration devices inside the condenser. Together with a long service life and an unsatisfactory condition of the vacuum system, operation regimes with increased dissolved oxygen concentration are often observed.

4. Case description

The authors, in accordance with the recommendations of [6], have reconstructed and studied the operating modes of the 200-KCS-2 steam surface condenser. The reconstruction included the installation of a "steam sparger" type device inside the hotwell. The principle of its work was condensate heating to the saturation temperature.
The condenser tube bundle scheme is presented in Fig. 3. This design is typical of the regenerative condensers of 60-70 years. The arrangement of tubes is the tape-like. The condenser is made of two-path, with a side arrangement of the air cooler.

![Figure 3. Tube bundle scheme of 200-KCS-2 condenser.](image)

Thermal tests were carried out with the nominal load of the steam turbine at different temperatures of cooling water at the condenser inlet. The lower temperatures of cooling water matched a higher concentration of dissolved oxygen. Throughout the tests, the air leakage rate of the vacuum system remained constant and exceeded the norm. The values of the dissolved oxygen concentration in the condensate were recorded after the steam-sparger was switched on after 15 minutes, to stabilize the water-chemical regime. Stationary chemical control devices were used as the oxygen meter.

![Fig. 4. Dissolved oxygen concentration reducing during thermal tests.](image)

The use of superheated steam from the regeneration system allowed necessary heating of the condensate. During the tests of the turbine unit at a load range of 100-40%, the activation of the device in operation allowed reduction in oxygen concentration in the main condensate by 2-2.5 times to the norms established by the PTE.

5. Conclusion

Based on the obtained results, the use of deaeration devices in turbine condensers seems appropriate to maintain the water-chemical regime over the entire range of loads.

As it is shown by the test results, the installation of a steam sparger increases the deaeration capacity. However, additional use of steam increases the specific heat consumption.
Undoubtedly, the high value of air leakages in the vacuum system, especially in the water volume of the condenser, significantly worsens the deaeration of water in the condenser.

It should be noted that in some cases, a decrease in the concentration of dissolved oxygen did not allow reaching the regulated values. To improve the efficiency of the steam sparger, both a design change and an increase in steam flow rate are necessary.

References
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