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# DESIGN OF CLOSED COOLING SYSTEMS ON THE EXAMPLE OF THE STEEL MILL SILESIA IN RYBNIK

The main purpose of the paper was to show the possibility of closing the cooling water circuits in the hardware factory „Silesia" in Rybnik. To this end for the selected groups of machines representative of two cooling cycles, the effect of cooling process on physico-chemical characteristic of water has been analysed. The results of analysis allowed to suggest the coalescence on the coke filter as the most efficient process for the removal of pollutants from cooling water. Cooling cycles are to be replenished with make-up water treated in preliminary chlorination and chemical $CO_2$ binding, as well as in filtration process. For the conditions operational periodical chlorination and batching of corrosion inhibitors to the circulating water have been recommended. The concept presented in this paper may be treated as a simple cooling circuit.

## 1. INTRODUCTION

In many branches of the industry a percent of the water uptaken is used for cooling. In view of the ever increasing water efficiency, the separate plants are obliged to modernize the methods of water and wastewater disposal. One of the methods reducing the consumption of water is the introduction of a closed cooling system. The paper presents a concept of closing the cycle of cooling water in the steel mill SILESIA.

At present the steel mill has an open cooling system, to which the water is supplied from two sources, from flow reservoir on the river Ruda (without treatment) and from municipal water supply system. The planned extension of the steel mill includes also the modernization of the water and wastewater disposal. According to the plans the open system is to be changed into the closed system of machine and equipments cooling.

The foredesign has been performed in the Department of Technology and Automation of Water Supply and Sewage Systems, Kraków Division of the Institute of the Environment Control, and allowed to develop technological designs for solving this problem.

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## 2. WATER QUALITY CHARACTERISTICS IN COOLING SYSTEMS

The investigations were initiated by determining the parameters required from water in cooling systems, basing on the Polish literature data [3, 4, 5, 7, 8, 9, 10] and the authors own experiments, namely: temperature — up to 298 K, pH — 7.2–8.5, sulphates — to 450 mg $SO_4/dm^3$, chlorides — to 500 mg $Cl^-/dm^3$, total iron — to 1 mg $Fe/dm^3$, manganese — to 0.15 mg $Mn/dm^3$, total hardness — to $28^0$ n (10 mval/$dm^3$), carbonate hardness — 1.4–4.0 mval/$dm^3$, free $CO_2$ — to 3 mg $CO_2/dm^3$, suspensions — 20–30 mg/$dm^3$, ethere extract — to 15 mg/$dm^3$, growth of microorganisms — inadmissible.

The purpose of the measurements and investigations performed was to determine the effect of cooling of 5 groups of machines — considered to be representative — on the water quality, and to establish to what extent its properties differ from the standards given above.

The first planned closed cycle is to take the water from the cooling of machines in the Department of Enamel Shop. Seam welders and hump welders being recognized as the representatives of this cycle, the water quality was tested prior to and post their indirect cooling. In view of the lack of theoretical reasons for distinct changes in the pollution degree of the water (besides heating) the results have been analysed by using statistical methods. Results of analyses (performed at every 1 or two weeks) of inflowing water and after cooling the machines, were averaged and compared (fig. 1). When the averages showed the differences, the distribution of the given characteristics of the water was tested by chi-square test. When the distribution was close to the normal one, the statistical significance of differences in water characteristics before and after cooling was stated by using Student's tests.

In first cycle significant differences have been found water before and after cooling of hump welders, which used only 11% of the total amount of the cycle. Thus this water before being recycled may be only cooled. The temperature increments were usually low (not exceeding 8 deg) and depended on the temperature of inflowing water. It has been proposed to assume the average temperature increment from maximal daily increments ($\Delta t = 4.1$. deg) as a reliable increment in the calculations of coolers.

The second independent closed cooling system will take the water from cooling of machines in the section of refrigerators and from the refrigerating compressers station. Injection moudling machines, refrigerating compressors and vacuum have been assumed as the representatives of this cycle. To establish the effect of cooling of these machines on the quality of water the temperature cooling water was measured and its physico-chemical properties were analyzed. Average values of the selected properties of water before and after cooling are presented in fig. 2.

In water cooling of vacuum and injection moulding machines besides the increment of temperature (7.0 deg on the average) a statistically significant increase in the amounts of suspensions and substances extracted by petroleum benzine has been stated. In water after cooling of refrigerating compressors apart from the already mentioned changes — the

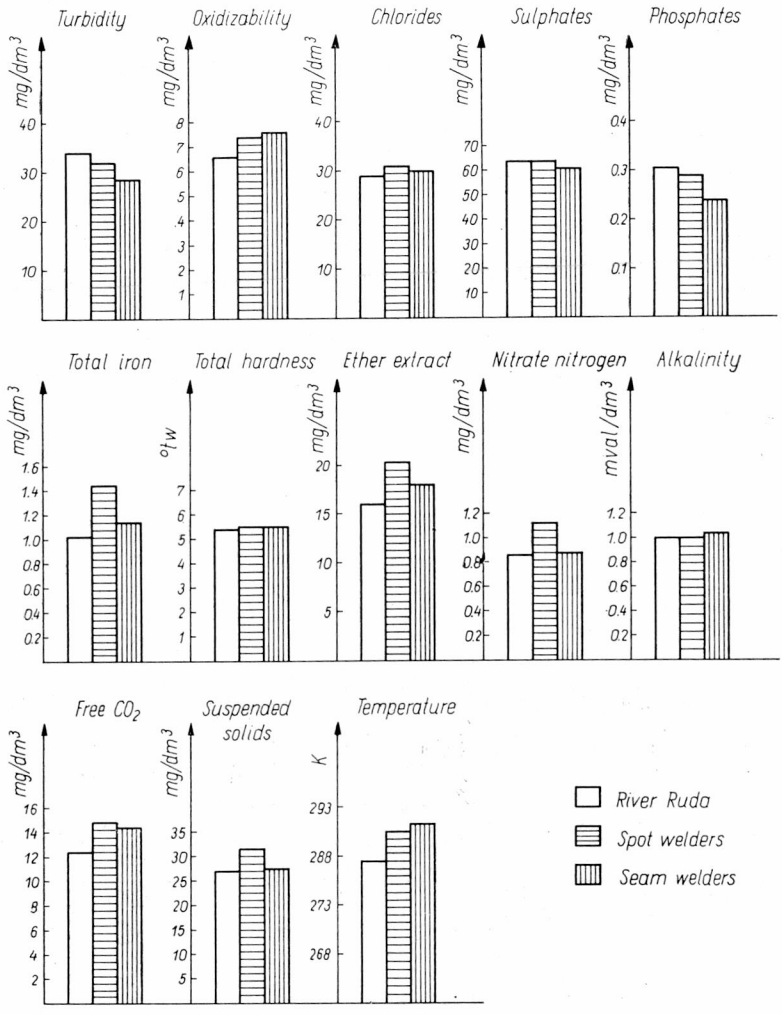


Fig. 1. Mean values of water properties examined systematically before and after cooling of machines belonging to the system I

Rys. 1. Zestawienie wartości średnich systematycznie badanych własności wody przed i po chłodzeniu maszyn wchodzących w skład obiegu I

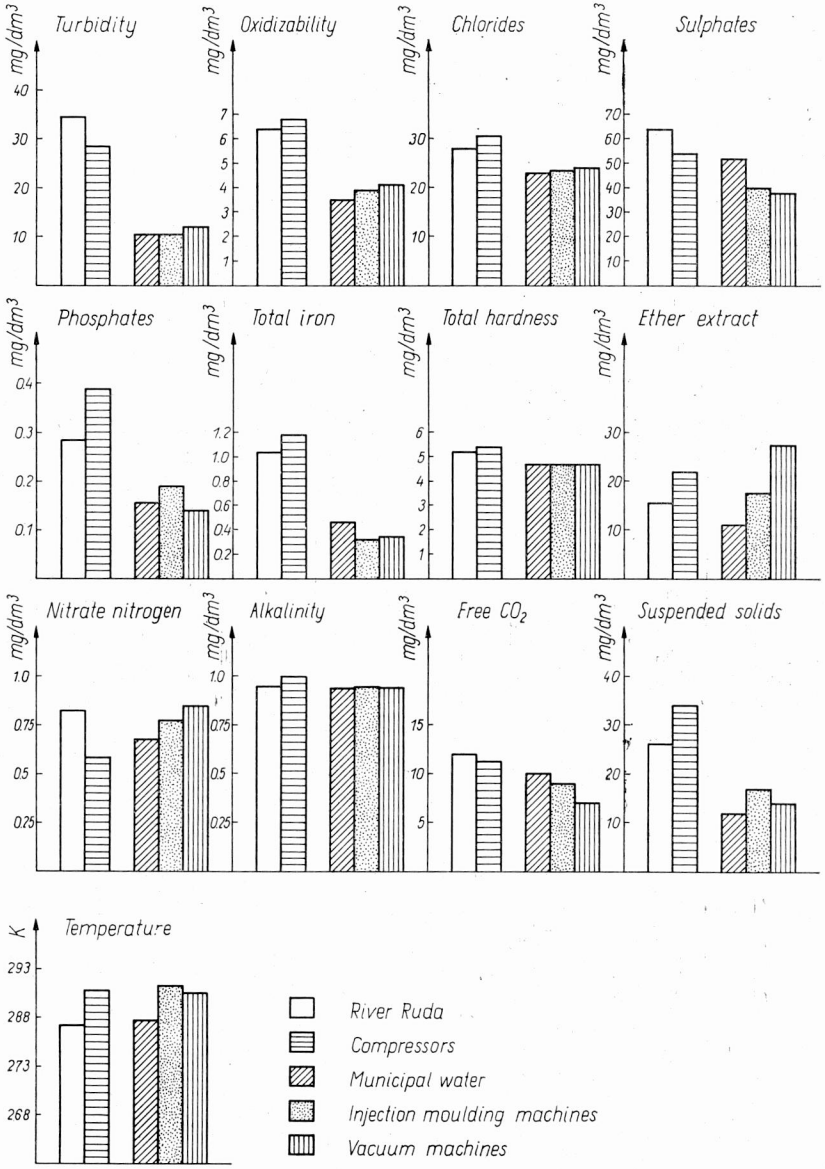


Fig. 2. Mean values of water propertries examined systematically before and after cooling of machines belonging to the system II

Rys. 2. Zestawienie wartości średnich systematycznie badanych własności wody przed i po chłodzeniu maszyn wchodzących w skład obiegu II

increased content of total iron (probably washed from rusty coolers) has been stated. In view of the stated increment in impurities the water after cooling before being recycled should be not only cooled by also treated (purified).

## 3. INVESTIGATIONS OF POLLUTANTS REMOVAL FROM WATER AFTER COOLING

Three series of laboratory tests have been performed on deoiling of water after cooling of machines by its settling, and on suspension removal by sedimentation.

Since these methods gave no satisfactory results the coalescence process more and more often used to removal of emulsified oils [1, 2] has been applied and its usability in deoiling and suspension removal from the water post cooling was checked.

The coalescence process in which the degree of oil and fat dispersion is decreased, is usually conducted under dynamic conditions on filtration bed with adequate filling material. The application of this method to removal of pollutants from the water in cooling system seems to be particularly suitable because of mechanical and sorptive properties of the bed involved additionally in this process.

The efficiency of the process was checked by tests conducted on a semi-pilot scale by applying a filtre with coke bed 120 cm high and grain sizes ranging from 0.5 to 2.5 cm. This method gave the required decrease in the contents of oils and fats (82.5% on the average). High degree of removal (98%) was also obtained in case when the contents of substances extracted by benzine oil was abnormally increased (emergency state — 245 mg/dm$^3$).

If the contents of suspensions in water were small (to 10 mg/dm$^3$) the degree of their removal on coke filter was rather low (18%), whereas at the content of suspension varying within 15–50 mg/dm$^3$ the average removal amounted to 60%.

Thus the coalescence process conducted on filtre with coke bed appeared to be efficient in water treatment before its recycling.

## 4. TECHNOLOGY OF SUPPLEMENTARY WATER TREATMENT

It will be necessary to supplement the closed cycles of cooling water with fresh water taken from the reservoir on the river Ruda. The investigations of water quality in the reservoir allowed to state that this water as a cooling medium is characterized by the following advantageous properties: low hardness (thermostability), weak salinity and low permanganate value, whereas disadvantageous properties such as high concentration of iron and biogenic elements conductive to biological growth, presence of corrosive $CO_2$ and large amounts of suspension will be corrected in the following treatment processes:

— chlorination with sodium hypochlorite — 1 mg/dm$^3$ $Cl_2$ for 15 min. To inhibit a mass growth of algae (water blooming) the dosage should be increased to 5 mg/dm$^3$ $Cl_2$.

The quantities of dosage obtained experimentally are in conformity with the literature data [10]

— chemical bounding of $CO_2$ by calcium in doses ranging within 7–10 mg/dm$^3$ CaO,

— filtration on filter with course-grained bed ($d_{min} = 0.8$ mm, $d_{max} = 3.0$ mm, $Kr = 1.25$), the filtration rate 10 m/h.

The selected treatment technology of water from the reservoir on the Ruda river was checked by investigations, which allowed to make precise the separate processes.

## CONCLUSIONS

The presented results of investigations were used in conception allowing to close cooling systems. This conception is shown in block diagram — fig. 3.

In view of localizations 3 independent cooling systems are planned in the steel mill Silesia. In the system I, water after cooling the machines and equipments will pumped only on ventilation cooling bed, to decrease its temperature and then recycled.

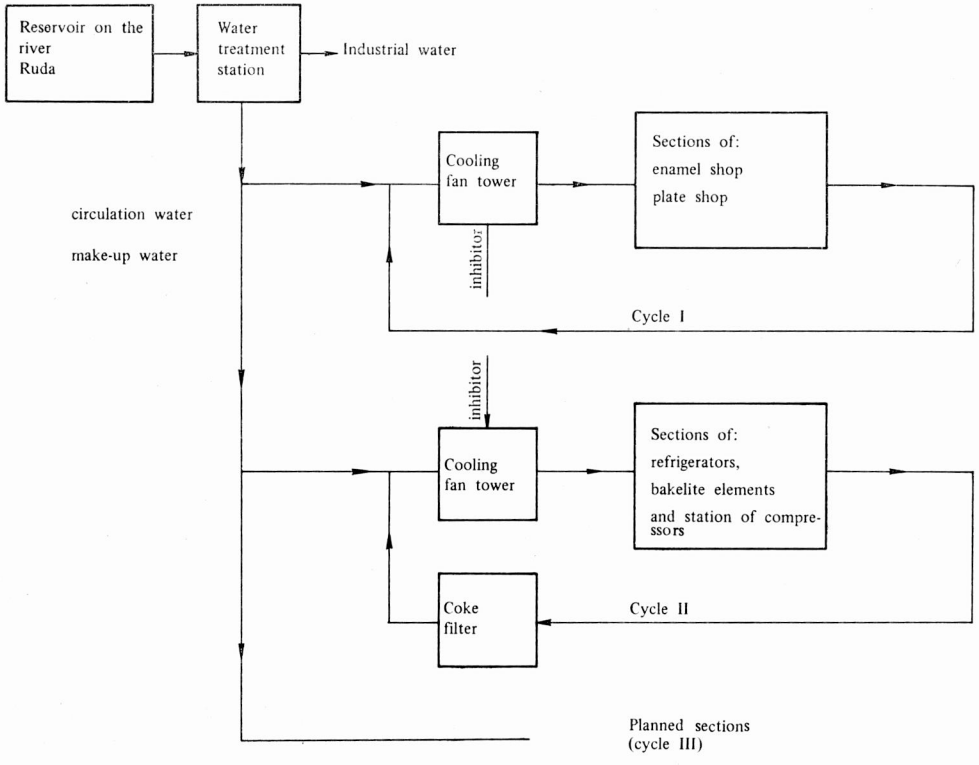


Fig. 3. Block diagram of cooling systems

Rys. 3. Schemat blokowy obiegów wody chłodniczej

In the system II cooling water before being recycled will be treated on coalescent filter with coke bed and cooled on the cooling bed. Filtration through coke bed should simply and efficiently prevent water cumulation of fats and suspensions in water.

In order to protect both systems against corrosion and sediments it has been assumed that an inhibitor with anticorosion and antisodium properties will be batched into the tanks under cooling beds, and that its concentration in circulation water should not exceed 30 mg/dm$^3$.

The ultimate conception of the system III will be established after the extension of the plant is completed. To supplement the circulation system the water will be taken from the reservoir on the river Ruda and treated in primary chlorination, chemical compound of $CO_2$ and filtration of course grained sand bed. Water prepared in such a way to the circulation system will be directed to the cooling bed which should protect its structural element against biological growth.

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## OPRACOWANIE TECHNOLOGII ZAMKNIĘTYCH OBIEGÓW WODY CHŁODZĄCEJ W ZAKŁADZIE WYROBÓW METALOWYCH „SILESIA"

Przeprowadzono roczne badania własności fizykochemicznych wody przed i po chłodzeniu 5 reprezentatywnych grup maszyn. Po statystycznym opracowaniu otrzymanych wyników analiz stwierdzono, że woda zostaje nie tylko podgrzana ale i zanieczyszczona. Obserwowano przyrost ilości olejów i tłuszczów oraz zawiesiny. Do usuwania tych zanieczyszczeń z wody pochłodniczej zaproponowano filtr koalescencyjny z wypełnieniem koksowym i sprawdzono skuteczność jego działania w skali ułamkowotechnicznej. Stwierdzono, że filtr koksowy stanowi dobre zabezpieczenie przed kumulowaniem w wodzie obiegowej olejów i tłuszczów oraz zawiesin, a także oderwanych obrostów biologicznych. W artykule podano również opracowanie technologii uzdatniania wody uzupełniającej obiegi oraz zarys ostatecznej koncepcji zamkniętych obiegów wody chłodniczej w Zakładzie Wyrobów Metalowych.

## SCHLIESSUNG DES KÜHLWASSER-KREISLAUFES IN EINEM METALLURGISCHEN WERK

Die physikalisch-chemischen Eigenschaften eines im Kühlkreislauf geführten Wassers vor und nach der Kühlung wurden ein Jahr lang untersucht, wobei es sich um Kühlung 5 verschiedener Maschinengruppen handelte. Eine statistische Auswertung der Befunde bewies nicht nur eine Aufwärmung sondern auch eine wachsende Verunreinigung des Wassers, vor allem in Bezung auf den Petrol-Ätherextrakt und Schwebestoffe. Vorgeschlagen wurde eine Zwischenschaltung eines Koaleszenzfilters mit Koksschüttung, welcher — in semi-technischem Maßstab getestet — sich bewährt hat. Dieser Filter entfernt aus dem Wasser Öle, Schwebestoffe wie auch den abgeschwemmten biologischen Rasen. Der Bericht enthält Hinweise zur Wasseraufbereitung und zum Schließen des Kühlwasser-Kreislaufs im erwähnten Werk.

## РАЗРАБОТКА ТЕХНОЛОГИИ ДЛЯ ЗАМЫКАНИЯ ЦИКЛОВ ОХЛАЖАДАЮЩЕЙ ВОДЫ НА МЕТАЛЛИЧЕСКОМ ЗАВОДЕ

Проведены годичные испытания физико-химических свойств воды до и после охлаждения 5 репрезентативных групп машин. После статистической обработки полученных результатов анализа установлено, что вода оказывается не только подогретой, но и загрязненной. Отмечалось приращение количества смазок и жиров, а также суспензий. Для удаления этих загрязнений из воды, употребленной для охлаждения, предлагается ковалесцентный фильтр с коксовым заполнением; его эффективность проверена в дробнотехническом масштабе. Обнаружено, что коксовый фильтр является хорошей защитой от накапливания в оборотной воде масел, жиров и суспензий, а также отрванного от стенок биологического оброста. В работе представлена, кроме того, разработка технологии подготовки воды для пополнения циклов и сформулирована полная концепция замкнутых циклов охлажадающей воды на металлическом заводе.