Environment Protection Engineering

Vol. 4 1978 No. 1

COMMUNICATION

ANDRZEJ GEISSLER*

AUTOMATIC NEUTRALIZATION OF WASTEWATER FROM THE RAILWAY ROLLING STOCK WASHING STAND

A cleansing agent used to wash the railway rolling stock is known under its trade-mark dekrasol. It is composed of acid (9P-94%), surfactant "alfenol 8" (4–8%) and octyl alcohol (2%). The examined samples of wastewater from the washing stand were characterized first of all by low pH value (2 to 5) due to the presence of oxalic acid (up to 700 mg/dm³). They contained surface active substances — up to about 30 mg/dm³, total iron — up to about 350 mg/dm³, and up to 800 mg/dm³ solids, while dissolved substances amounted to about 1400 mg/dm³ [1], [2]. The purpose of the investigation was to design an automatic neutralization system for wastewaters from the washing stand. Neutralization of wastewater is one of the elements in the process of treatment in a closed technological cycle, comprising a washing stand, and wastewater treatment-plant. (fig. 1). The proper choice of the monitoring and control equipment was preceded by identification of the object controlled system, which consisted in determining its static and dynamic properties. Neutralization takes place in reaction chambers equipped with agitators. Wastewater is continuously pumped through these chambers from the surge tank, at a constant flow rate (fig. 2).

Lime milk should be metered automatically to the reaction chamber so that the pH of wastewater after leaving the reaction chamber is constant and equal to 6.5. In such a manner the pH of neutralized wastewater is the controlled value (parameter) of the considered controlled system, while flow rate of lime to reaction chamber is the correcting variable; the initial varying pH of incoming wastewaters is a disturbing variable (fig. 3). It should be expected that variation in the disturbing variable will be slow, since the reaction chambers are preceded by a tank of large capacity, temperature oscillation is negligeable, and the rate of wastewater flow through the chambers practically constant.

Static properties of the object are represented by curves of neutralization pH $= f(Q)$, where Q — flow-rate of lime milk determined by calculations and experimentally. Computational method was based on simplified assumption that reaction of neutralization occurs between calcium base and aqueous solution of oxalic acid. Concentrations of both reagents resulted from technological requirements. On the other hand, the measurements were performed for aqueous solutions of dekrasol and then for wastewater sampled from washing stand [1], [2], [3]. The analysis of the results obtained allowed to formulate the following conclusions:

1. In the vicinity of equivalent point pH $= 7$ non-linear static characteristic may be approximated by a straight line, and amplification coefficient of the object can be determined.

2. The directional coefficient of this straight line, and at the same time the amplification coefficient of the linearized controlled system is smaller for the experimental curves, as compared to the theoretical ones. Thus the assumed simplification of calculations sharpens the criteria according to which the control equip-

* Research Institute for Environmental Development, Cracow Division, Cracow, Poland.

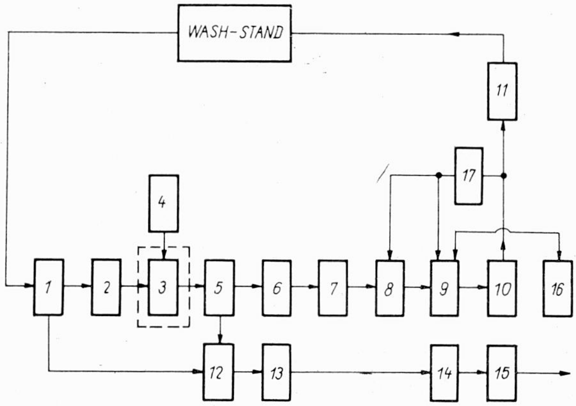

Fig. 1. Layout of the rolling stock wash-stand wastewater treatment plant

1 — pane oil trap with settling tank, *2* — wastewater pump station with equalization tank, *3* — reaction chambers, *4* — lime milk tanks, *5* — final flocculation clarifier, *6* — neutralized wastewater wet well, *7* — pumping station, *8* — rapid filter, *9* — adsorption units, *10* — technological water reservoir, *11* — technological water pumping station, *12* — sludge wet well, *13* — sludge pumping station, *14* — sludge lagoon, *15* — supernatant holding tank, *16* — activated carbon storage, *17* — wash water pumping station

Rys. 1. Schemat technologiczny oczyszczalni ścieków z myjni taboru kolejowego

1 — płytowy łapacz oleju z osadnikiem, *2* — pompownia ścieków surowych ze zbiornikiem wyrównawczym, *3* — komory reakcji, *4* — zbiornik mleka wapiennego. *5* — osadnik pokoagulacyjny, *6* — zbiornik czerpalny ścieków zneutralizowanych, *7* — pompownia, *8* — filtr pospieszny, *9* — komory adsorpcji, *10* — zbiornik wody technologicznej, *11* — pompownia wody technologicznej, *12* — zbiornik czerpalny osadów, *13* — pompownia osadów, *14* — laguna osadowa, *15* — zbiornik wód nadosadowych, *16* — magazyn węgla aktywnego, *17* — pompownia wody płucznej

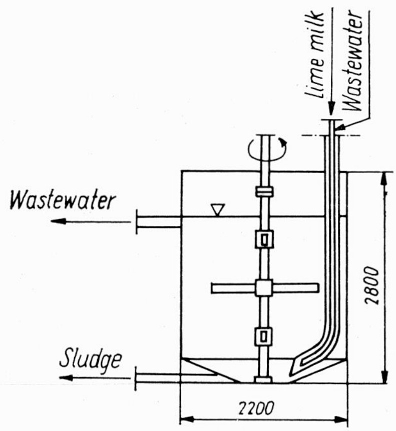

Fig. 2. Reaction chamber

Rys. 2. Komora reakcji

ment is selected (fig. 4). Chemical reactions occuring during neutralization of oxalic acid contained in wastewater are of ionic type, i.e. characterized by considerable rates. The time of reaction depends above all on the mixing of components. It may be assumed with high accuracy that the dynamics of the neutralization process is identical with the dynamics of mixing [6].

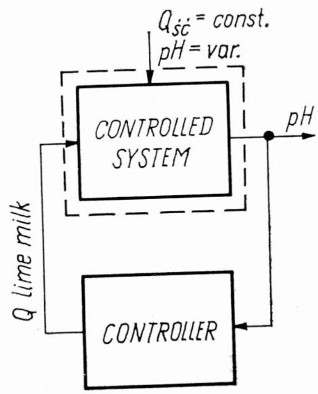

Fig. 3. Control system

Rys. 3. Obiekt regulacji

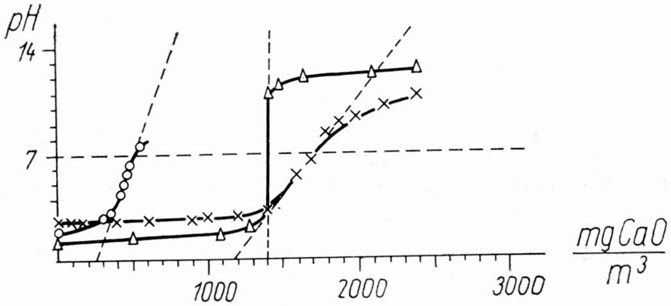

Fig. 4. Neutralization curves: o-o-o neutralization of wastes from wash-stand, △-△-△ neutralization of Dekrasol (2.5g/dm^3) – theoretical curve, x-x-x neutralization of Dekrasol (2.5g/dm^3) – experimental curve

Rys. 4. Krzywe zobojętnienia: o-o-o zobojętnienie próbki ścieków z myjni, △-△-△ zobojętnienie roztworu Dekresolu (2,5g/dm^3) – krzywa teoretyczna, x-x-x zobojętnienie roztworu Dekresolu (2,5g/dm^3) – krzywa doświadczalna

While working with the system of automatic neutralization reaction chambers were not at the author's disposal, therefore work was confined to analytical determination of the dynamic characteristics of the system. Mathematical analysis of the mixing process is quite complex, and moreover, a number of accompanying phenomena have not been satisfactorily explained. Nevertheless for the system of automatic control an approximate mathematical model of mixing dynamics is sufficient. The approximation most often used in the automatic control theory consists in the fact that differential equations basic for the calculations of the system transmittance are derived assuming first an ideal mixing, and then the delay in mixing, i.e. the time passing from the development of disturbances (changes in concentration) till the moment in which this change is stated at the site where the sensor is installed [5], [6]. Transmittance of the linearized model of the regulated system, calculated in this way has the form

$$G(s) = \frac{K \cdot e^{-T_m \cdot s}}{1 + T \cdot s}$$

where

$G(s)$ – system's transmittance;

K — amplification coefficient of the system, determined from static characteristics;
T — time constant of the reaction chamber

$$T = \frac{W}{Q}$$

W — volume of wastewater in reaction chamber,
O — flow rate of wastewater through reaction chamber,
T_m — dead time,
s — Laplace's operator.

As far as the quantities mentioned above are concerned we should calculate dead time T_m consisting of the time of mixing delay T_{m1} and time of transport retardation T_{m2} of the reagent (lime milk) along the route: final control element — reaction chamber. It is generally assumed that T_m is (2–4) t_c, [6]. The time t_c is the circulation time of the reaction chamber, given by the formula:

$$t_c = \frac{W}{E},$$

where
E — pumping efficiency of the agitator.

The knowledge of the mathematical model of the system, i. e. of the equation of the system's transmittance, allowed to calculate in an easy way the required parameters of the system of automatic pH control. Thus, amplification coefficient of the controlled system provides information indispensable for determining a quantitative balance of lime, and consequently for the adequate choice of the pump, feeding system, control valve, servo-motor, sensor and pH-meter. Time constants T and T_m — with the known requirements with respect to the control performance — make possible the choice of the structure of the controller. By calculating amplification coefficients for the particular elements of the control system (valve, servo-motor, meter) and taking advantage of the amplification factor of the system calculated earlier, the amplification coefficient of the controller has been determined, and then — based on the criterion of non-periodic stability — optimal settings of the controller. The assumed performance criterion assures transients without overshootings with a minimal duration time, and stable operation of the system.

The last procedure was to select the type of controller based on its structure and required settings. The calculations performed resulted in the control system presented in fig. 5.

CONCLUSIONS

The investigations have evidenced that the task, i. e. automation of the neutralization process — can be realized in a single circuit control system, although the automatic regulation of the neutralization process itself is very difficult. This was possible due to:

1. The constant flow rate of wastewater through the reaction chambers;
2. Low value of dead time T_m (intense stirring);
3. Advantageous relation between the time constant T and the dead time T_m, $T \geqslant T_m$;
4. Expected adjustement of the wastewater pH in the tank preceding the reaction chambers;
5. Location of the bed with activated carbon following the neutralization process tanks — which, because of alkaline properties of carbon, allows to conduct the neutralization to the pH value of only 6.5.

The greatest difficulties faced during the experiment were the lack of data characterizing dynamic properties of the controlled system (reaction chambers).

In view of the ever increasing automation of the technological processes in water and wastewater treatment it seems advisable that the dynamic properties of the equipment produced be defined by their designers and producers and put in catalogues of products together with the usually provided specification. This will enable a much better and more accurate designing of the automatic control systems.

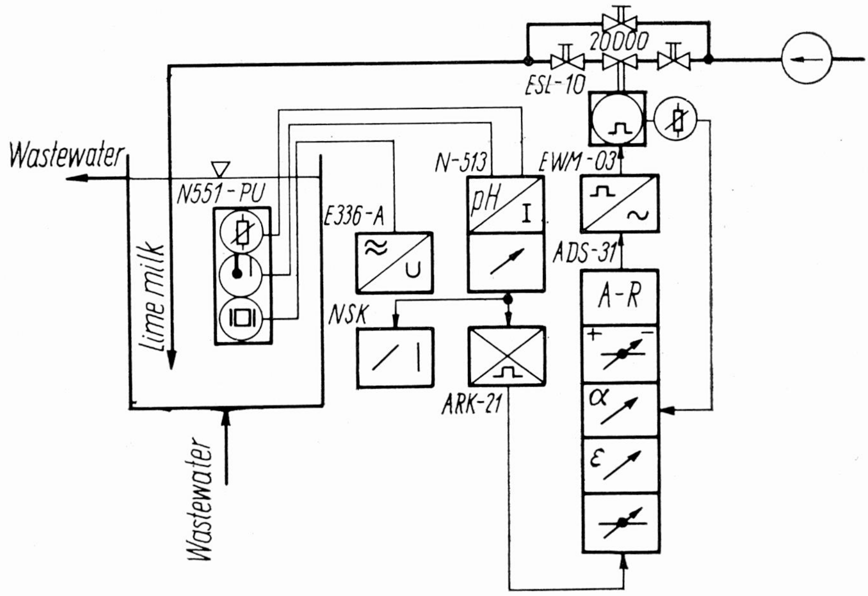

Fig. 5 Block layout of the controlled system
Rys. 5 Schemat blokowy układu regulacji

REFERENCES

[1] Erndt E., *Treatment of wastes from the railway rolling stock, with particular reference to removal of detergents and oxalic acid*, Inst. Meteor. Water Res., (in Polish), Cracow 1974.

[2] Erndt E., as above; Part II., Cracow 1974.

[3] Geissler A., Geissler M., Okraska E., *Automation of the neutralizing agent addition to rolling stock wash wastes*, Res. Inst. Environment. Develop., (in Polish), Cracow 1975.

[4] Geissler A., Maciejowski W., Nowak T., *Automation of rolling stock wastewater neutralization*, Res. Inst. Environment. Develop. (in Polish), Cracow 1975.

[5] Górecki H., *Analysis and synthesis of retarded regulation control systems*, (in Polish), WNT, Warsaw 1971.

[6] Harriot P., *Chemical process control*, WNT, Warsaw 1967.