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MODERNIZATION OF THE AUTOMATED SYSTEM TECHNOLOGIAL PROCESS OF SALT EXTRACTION

This article provides the development of a new automated system for the technological process of salt extraction, based on the principles of integrating existing technologies and innovative developments. The results of testing this system will be presented, an analysis of its effectiveness, economic benefits will be carried out, and recommendations for its use will be given.

The paper considers the existing salt extraction technologies and automated control systems used in production, analyze their shortcomings and problems, raises issues related to product quality, energy efficiency, economy and safety of salt extraction technological processes. The technological process of salt crystallization is considered as a model. This model implies a two-stage adjustment of the cooling temperature of the hot salt solution at the outlet of the heat exchanger. This allows you to see the effectiveness of the implementation of the improved method of salt extraction. The paper will present an integrated approach to the problems of automating the technological process of salt extraction, which will provide new knowledge and competencies in this area.

Keywords: technological process, automated systems, salt extraction, improvement, management, product quality.

Introduction

Currently industry plays an important role in the economy, one of which is the extraction of mineral resources such as salt. Automated salt mining process systems have become increasingly popular and in demand among manufacturers due to the growing demand for this product, as well as the need to optimize production processes and improve product quality.

Salt mining is widely used in almost all areas of industry and is one of the most important natural resources on earth. First of all, the mineral is vital in the food industry, since not a single concentrate, not a single food additive can do without the use of this component. In medicine, various medical preparations and injection solutions are created on the basis of salt to strengthen the immune system [1]. In the chemical industry, the mineral is used to produce chlorine and hydrochloric acid. Oil and gas business uses the properties of salt to create a special solution when drilling wells.

Salt is now available to everyone. This food product is continuously consumed by a person, so its reserves must be replenished every day. To ensure the efficiency and safety of the salt extraction process, it is necessary to use modern methods and techniques, as well as automated control and monitoring systems. This article is relevant and has great practical significance. At the moment, existing systems need to be improved and modernized in order to ensure a more efficient and safe operation in the salt production.

Materials and methods

Modernization of the automated system of the technological process of salt extraction may include the following changes:

- Software update. New programs may provide more control over the process and provide more information about production.
- Installation of new equipment. More modern equipment can be used to improve process control and management.
- Implementation of a monitoring and control system. The new sensors and instruments will enable the mining process to be monitored more precisely, which will increase productivity and safety.
- Introduction of automatic control system. The automatic control system will allow faster and more accurate response to changes in the production process.
-Training. Training staff to work with new equipment and software, as well as understanding how changes will affect the process, will help to implement new technologies more efficiently.

Modernization of the automated system of the technological process of salt [2] extraction will improve the efficiency and safety of the work process, which, in turn, will lead to cost reduction and increase in profits.

Traditionally, technical rock salt is mined in mines at great depths, natural layers of rock salt deposits are developed using special machines, the salt is crushed and rises to the surface, where it subsequently undergoes special processing and grinding into small fractions. Mined from great depths, rock salt is the most environmentally friendly among all existing types of technical salt. Salt is also mined by natural evaporation of saline solutions obtained by dissolving salt layers lying close to the surface of the earth with water. Basically, the extraction of self-planting technical salt is carried out in salt lakes. When collecting salt from the bottom of lakes, various techniques are used. The use of modern technologies at this stage of salt extraction implies the continuous operation of multi-ton combines, bulldozers and tractor loaders installed on the railway tracks.

There are a variety of methods to produce purer edible salt suitable for human use. Among them, there is a rock salt recrystallization method, which we will consider as an automation model. This method makes it possible to obtain pure salt in a cheaper way than by vacuum evaporation. To begin with, rock salt is mixed with the mother liquor remaining after secondary crystallization. Then, the salt pulp is stirred with live steam, the condensation of which leads to the dissolution of salt crystals at 100–105 °C. The undissolved part containing impurities (anhydrite, etc.) is separated in a settling tank, and the hot solution is sent for crystallization in two stages – when it is cooled to 80 °C, then to 50 °C. Salt from the crystallizers is squeezed out in centrifuges and dried. This method also has an advantage over vacuum evaporation from an economic point of view, since it does not require such an amount of steam consumption.

The process of two-stage cooling of a hot solution by using a food heat exchanger is taken as a basis. Equipment of this type is actively used in many industries. The unit works on the principle of surface heat exchange, it is used for heating, cooling, pasteurization and evaporation of various products. As an automated system, let's consider a tubular heat exchanger, which provides a high flow rate of liquid through the pipe, which reduces the likelihood of scale formation on the walls caused by the chemical properties of salt. Shell and tube heat exchanger manufacturers divide the design of the heat exchanger into three main parts, such as the header for the front end, the casing and, directly, the header for the rear end, which are indicated by special symbols. The work of a shell-and-tube heat exchanger is that cold and hot working environments move through different shells, and heat exchange occurs in the space between them [3].

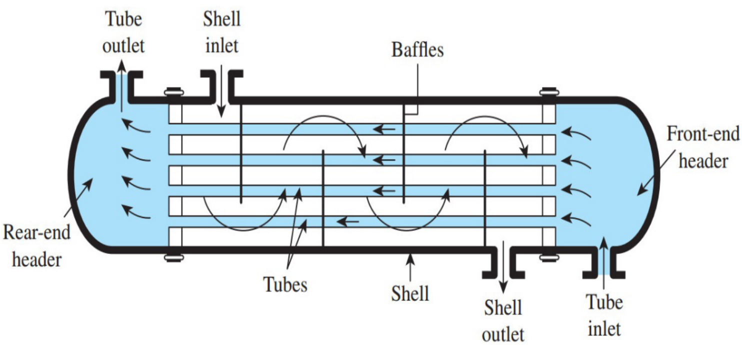

Figure 1 – Shell and tube heat exchanger

Shell and tube heat exchangers are the most popular types of exchangers. It is constructed of 2 main parts: a big shell of sphere type and a few amount of tubes that are functioning inside this. These types usually run from one side to the other as well as go in U-shaped way. The most beneficial and not complex design of this type of heat exchangers is with tubes glued to the shell. Furthermore, it is easy to clean these tubes by using special procedures. It is built the way that is able to work at high level of thermal conditions, especially the temperature expansion that occurs in the thermal change. The tubes have to be strong, resistant to any kind of corrosion and must withstand the fluid medium. The working principle is based on the 2 nd thermodynamics law, stating that the heat moves from one part to the other according to the thermal difference. As a fact, heat flows from a hot part to the colder one. The cooling source, whether water, steam, ethanol is transferred through the tubes inside the shell configuration of a device. However, the medium to be cooled will circulate through these channels inside the shell structure.

The main benefits are that the capacity can be enlarged if we process the plates in pairs and it is not so difficult to maintain them. Moreover, in comparison with the previous type of exchanger, it can be easily cleaned, without extra reassembling. But the cost is also expensive, due to the plates that are made from Titanium. Moreover, because of this, other materials are tend to corrosion process. Finally, if there is something to fix at inner part of the exchanger, it is much difficult to accomplish due to the construction [4].

Results and discussion

In the scheme, there is a process of heat exchange system, described by the elements and special process. Thus, in a standard heating process there are main elements, like reactor, shell and a special tube heating system. The liquid in the reactor`s outside part is placed in the special tank. This storage tank submits the liquid to the shell and tube heat exchanger by pumps and valves. By using the steam, that heats the fluid to the satisfactory set point level with the help of a boiler. Finally, this heated steam gets in from the boiler and equally flows among the tubes. And by heating this liquid with the steam, we get a satisfactory level of point. By this way hot steam flows through the tubes and the fluid passes the shell and tube system. Moreover, there is a controller, acting in a reverse way and the valve, so we have a feedback control loop system.

The main sensing tool that is used to apply in this feedback process is a thermocouple. Consequently, the output temperature of the fluid is measured by the following thermocouple and is forwarded to the transmitter. This results in the signal of 4–20 mA. Further, the out range is then transmitted to the controller. This unit applies the algorithm of the control that makes comparison of the output range with the set point, after that created special conditions for the final control unit.

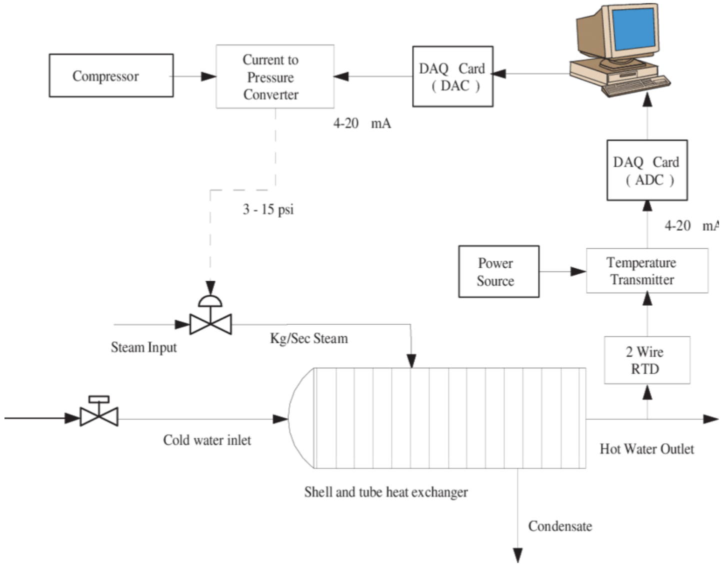

Figure 2 – Schematic diagram of heat exchange process

The actuator is represented as a converter of current to pressure. It means that it obtains the output of 4–20 mA and changes it to the pressure signal in the standardized form, giving a result value of 3–15 psig. The valve depends on the controller conditions and works by its consequences.

The experimental data like response gains and time constants used in calculating the heat transfer process is summarized below. Linearized mathematical models of heat exchanger will be developed according to this data [5–7].

Table 1 – The values of the technical process

Reaction of the heat exchanger to the gain of steam flow	50 C/(kg/sec)
T_C (time constant)	30 sec
Reaction of the heat exchanger to the process change of gain of fluid flow	1 C/(kg/sec)
The capacity of the valve control	1.6 kg/sec
T_C (valve control)	3 sec
Temperature sensor`s range	20 C to 150 C
T_C (temperature sensor)	10 sec

The mathematical description of the thermal process in heat exchangers should be presented in the form of an analytical expression characterizing the change in temperature in the coolant flow over time. The simplest model of heat exchangers that one where heat is transferred through the wall between the primary and secondary coolants. In real heat exchangers, the heat exchange zones have a constant volume, the flow rates of heat carriers at the inlet and outlet from the zone are the same, and the heat capacity practically does not change within the operating temperature range.

In order to design a control strategy, it is necessary to correctly determine the mathematical model of the process, that is, to predict the behavior of a real object. Most control systems are nonlinear. As a solution to these problems, models of the first (FOPTD) and second (SOPTD) orders plus time delay are used. The general form of the FOPTD model can be expressed as follows:

$$G(s) = \frac{K_p e^{-\tau_D s}}{\tau s + 1}$$

The general form of the SOPTD model can be expressed as follows:

$$G(s) = \frac{K_p e^{-\tau_D s}}{(\tau_1 s + 1)(\tau_2 s + 1)}$$

In the above formulas K_p is the process gain, τ is the time delay, τ is the time constant of the first order system plus the time delay, and τ_1 and τ_2 are the time constant of the second order system plus the time delay. The parameters used are derived from the frequency response or open-loop hopping data, and the transient response data is used to measure time delays. When developing a model of the transfer function of a heat exchange system, the experimental data mentioned in table 1.

Table 2 – Transfer functions and gains of control process

Transfer function model of Temperature Sensor	$\frac{0.16}{10s + 1}$
Transfer function model of Disturbance	$\frac{1}{30s + 1}$
Transfer function model of Valve	$\frac{0.13}{3s + 1}$
Transfer function model of heat exchanger system	$\frac{50e^{-s}}{30s + 1}$
The process transfer function	$\frac{5e^{-s}}{90s^2 + 33s + 1}$

Transfer function modeling of Heat Exchanger process:

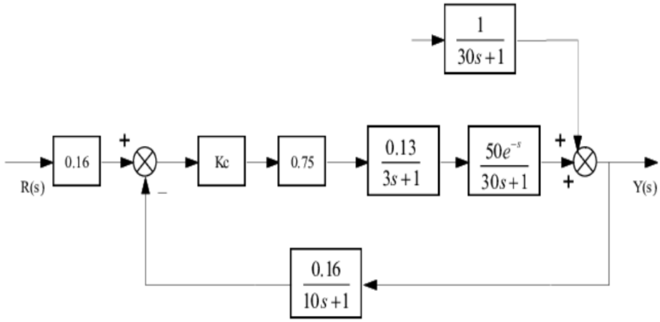

Figure 3 – Feedback control of Heat Exchanger system

The closed-loop control cycle calculates the actuator corrections based on the measured deviation of the controlled process from the set point. The constructed block diagram of the closed loop heat exchanger control system. There are different ways to configure a PID controller. Some methods are empirical methods (process response curve), some methods are based on the analysis of the frequency response of the system, and others are based on the minimization of performance. In most cases, the PID controller is adjusted for trial and error, which is equal to SP (set point) – PV (process value/measured value) in direct acting [8]. An ideal PID controller dependency in continuous time can be represented as

$$G_s\ (s) = K_c\ (1 + \frac{1}{\tau_i s} + \tau_d s)$$

where K_p is a proportional gain, τ_i and τ_d integral and derivative times respectively.

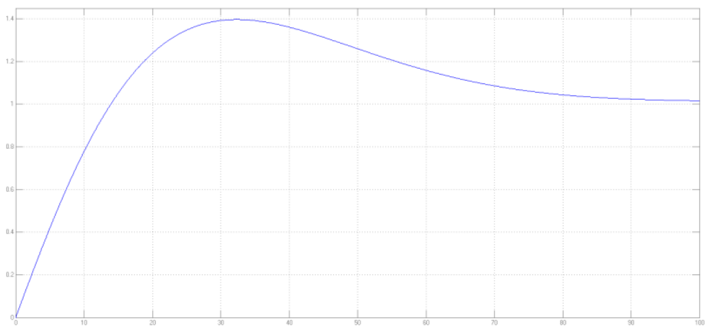

Figure 5 – Step Response of Feedback Control

Feed-forward control

The inherent limitations of a closed loop controller are that the controller acts after a disturbance distorts the desired control objective. If frequent failures occur, the closed-loop control will not be able to reach the desired steady state. Look-forward control is used to limit these kinds of downsides. Feedback control limits the deviation caused by disturbance, but feedback control works under one condition, namely, the disturbance must be measured or estimated. The feed-forward regulator's transfer function works on its own, so it works in conjunction with closed-loop control [9]. The transfer function of ideal feed-forward controller dependance can be represented as follows

$$G_{cf}(s) = -\frac{G_d(s)}{G_p(s)}$$

Here, minus sign deviation of disturbance transfer function $G_d(s)$ to the process transfer function $G_p(s)$ gives the transfer function of feedback-feed-forward controller $G_{cf}(s)$

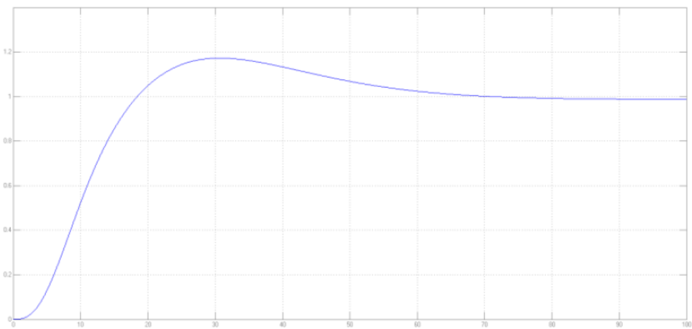

Figure 6 – Step Response of Feedback plus Feed-Forward Control

Simulation Results in MATLAB

On this step, it was considered two main parameters of different types of control loops. The first one is peak overshoot and second one is setting time.

Maximum overshoot: It shows the maximum deviation between the output and desired value.

Settling time: This parameter shows the time required to reach and stay a specified tolerance band of its final value.

Table 3 – Results for transient of controller

Control System	Maximum Overshoot (%)	Setting Time (sec)
Feedback PID Controller	39.7	115.6
Feedback plus feed-forward	18.3	88.2

Conclusion

Researches have shown that existing methods of salt extraction have their drawbacks. Based on the analysis, an assessment of efficiency was carried out, requirements for modern equipment were determined, and the main tasks of modernizing the technological process were described. New directions and technologies in production automation were also studied, which can be applied to salt extraction systems. The most effective strategies for the modernization of the system are determined, taking into account the specifics of local production. The project was implemented by installing a food heat exchanger, which ensures the efficient operation of the salt crystallization process. The introduction of a monitoring and control system for production units made it possible to automatically identify and correct problems in the technological process. The development of new equipment control algorithms has optimized productivity and increased product quality control.

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ТҰЗДЫ АЛУДЫҢ ТЕХНОЛОГИЯЛЫҚ ПРОЦЕСІНІҢ АВТОМАТТАНДЫРЫЛҒАН ЖҮЙЕСІН ЖАҢҒЫРТУ

Бұл мақалада қолданыстағы технологиялар мен инновациялық әзірлемелерді интеграциялау қағидаттарына негізделген тұз өндірудің технологиялық процесіне арналған жаңа автоматтандырылған жүйені әзірлеу ұсынылған. Бұл жүйені тестілеу нәтижелері ұсынылады, оның тиімділігіне, экономикалық пайдасына талдау жасалады және оны пайдалану бойынша ұсыныстар беріледі.

Мақалада тұз өндірудің қолданыстағы технологиялары мен өндірісте қолданылатын автоматтандырылған басқару жүйелері қарастырылады, олардың кемшіліктері мен проблемалары талданады, өнімнің сапасына, энергия тиімділігіне, үнемділікке және тұз өндірудің технологиялық процестерінің қауіпсіздігіне қатысты мәселелер көтеріледі. Модель ретінде тұздың кристалдануының технологиялық процесі қарастырылады. Бұл модель жылу алмастырғыштан шыққан кезде ыстық тұз ерітіндісінің салқындату температурасын екі сатылы реттеуді қамтиды. Бұл әсерді көруге мүмкіндік береді.

Кілтті сөздер: технологиялық процесс, автоматтандырылған жүйелер, тұз алу, жетілдіру, басқару, өнім сапасы.

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МОДЕРНИЗАЦИЯ АВТОМАТИЗИРОВАННОЙ СИСТЕМЫ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ИЗВЛЕЧЕНИЯ СОЛИ

В статье представлена разработка новой автоматизированной системы для технологического процесса добычи соли, основанной на принципах интеграции существующих технологий и инновационных разработок. Представлены результаты тестирования данной *системы, проведен анализ эффективности, экономических выгод и даны рекомендации по использованию.*

В статье рассматриваются существующие технологии извлечения соли и автоматизированные системы управления, используемые на производстве, анализируются недостатки и проблемы, поднимаются вопросы, связанные с качеством продукции, энергоэффективностью, экономичностью и безопасностью технологических процессов извлечения соли. В качестве модели рассмотрен технологический процесс кристаллизации соли. Моделирование подразумевает двухступенчатую регулировку температуры охлаждения горячего раствора соли на выходе из теплообменника. Исследование характеристик поведено в программной среде MATLAB, с использованием библиотеки Simulink.

Ключевые слова: технологический процесс, автоматизированные системы, извлечение соли, совершенствование, управление, качество продукции.

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