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PLC-BASED AUTOMATION SYSTEM INTEGRATION IN TEXTILE DYE DOSING MACHINE AND ENVIRONMENTAL SYSTEM DESIGN

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Abstract- The textile industry is one of the leading sectors in Turkey with the employment area, existing investment and high export rate. Therefore, it needs every innovation to be made. With the alkaline dosage automation, the manual preparation process was eliminated in the old system and the computer-controlled dye solution preparation process was started. Thus, the mixture required for the dyeing process is prepared as the dye machine demands. The viscose paint preparation process is prepared automatically and as the paint finishes, the amount of solution is instantly monitored by the sensor used on the machine. As the level drops, the machine automatically prepares the solution at the desired level. In this way, the prepared dye solution becomes usable without deterioration, the operator's workload is reduced and the contact with the dye is eliminated in terms of occupational health safety. The main objectives of the study are achieving an uninterrupted dyeing process, zero dye/chemical waste to the environment, decreasing unit costs while increasing the unit production amount. Therefore, the novel product obtained as a result of the study will have an important place in the textile sector thanks to its environmental and economic features.

Keywords: Dosing, Automation, PLC, Textile, Yarn Dyeing.

1. INTRODUCTION

Since the formation of industrial sectors, people have aimed to obtain quality and more products in a short time. In the light of studies based on these reasons, the distribution of work between people and machines has come to the fore and the foundation of automation systems has been laid.

The textile industry is one of the leading sectors in Turkey with the creation of employment, existing investment and a high export ratio [1]. Therefore, it needs every innovation to be made and has started to host important breakthroughs in automation.

Dye mixing processes are used in many different sectors. The textile sector comes first among these sectors. Yarn dyeing in the textile sector is carried out by many different methods. These are gradient dye, hank dye, arm skein dye, bobbin dye. Besides dyeing methods, the properties of dye and chemicals are important for obtaining the desired color quality in the dyed yarn. However, while obtaining the desired paint quality, keeping waste products at a minimum level and reducing the damage to the environment is much more important for manufacturers [1-21]. When these methods and production processes in large sectors are examined, it is seen that the smallest time and product loss can cause many damages [2].

All chemical products produced today consist of weighing many chemical materials in different amounts, mixing them with a mixer and delivering them. In the yarn dyeing industry, in order for the dyeing colors to have the desired appearance, different dye colors are automatically called from the warehouses where they are located according to a recipe created under laboratory conditions. They are taken in the desired quantities and mixed and applied to the fabric. The exact appearance of the colors will be an indicator of the quality of the system. If the mixing process is not sensitive, the colors will not appear as desired and production will fail [3]. As a solution to this situation, it is thought that turning the dye mixing system into automation will provide a significant advantage. Many researchers who want to make the advantages of the system visible have done their work in this direction. Giri et al. developed a mixer machine to obtain different paint colors. They used the primary colors yellow, red and blue in this machine. There are three tanks in the system and these tanks have integrated level sensors. The three main colors are in the container in which the mixing will take place is measured with the help of a weight measurement sensor, and the order color is obtained by mixing the available colors [4].

separate tanks and are sent to the tank where the mixture will take place with the hydraulic line and the solenoid valve connected to the PLC. The white color is in a fourth tank according to the desired order color. The weight of

Brindha, et al. realized the color acquisition system fully automated by using PLC, SCADA and Arduino. They obtained the color mixes they wanted in their study as a result of the color choices they assigned, thanks to the Matlab GUI. They created other colors based on the primary colors yellow, red and blue. The authors used Arduino to control the process and aimed to increase efficiency, reduce cost and profit [5].

Becerikli conducted a study that he addressed the problems arising in PLC and SCADA based weighing and dosing systems. In this study, he aimed to find solutions by addressing external factors affecting weighing quality. In this system, three different chambers are compared with pneumatically controlled weighing, pneumatically controlled weighing using manual correction coefficients and proportional pneumatic valve using PID controller [3].

Sebastian, et al., created a system based on mixing different colors in fixed proportions in the process of obtaining the desired dyes. They controlled this system, by using the SCADA system. The system consists of three parts. These parts are the dosing process, dye mixing, transportation and packaging. The dye mixed in the desired color ratio is transported to the packaging department thanks to the conveyor system. In this system, where the desired dye is obtained by using SCADA, the human effect is minimized and major mistakes that may occur in color creation are prevented [6].

Ahvad, et al., used the PLC system to mix green and blue colors and obtain the Cyan color. They have integrated a photoelectric sensor that can detect bottles on a conveyor belt powered by an AC motor. They used a color level sensing sensor to produce the same amount of product each time. The commands are created in the PLC and visualized the color production with SCADA on the computer screen [7].

These enlightening and guiding studies present the facilitation of the process is generally mentioned. In this study, in addition to improving the process; the dye-soda mixture that the worker needs to prepare for each dyeing process will be realized automatically in line with the need so that both the labor force will benefit significantly and the dye-soda mixture, which is produced as surplus and starts to thicken and deteriorates at the end of a certain period, will be prevented from being wasted. In short, this work will provide both economic and ecological benefits.

2. EXISTING SYSTEM FOR YARN DYEING

There are many dyeing methods applied for yarn dyeing in the textile industry. The general working principle of the system discussed in this study and will apply dosing automation is as follows. There are 4 painting barrels in the existing system as shown in Figure 1. The main dye obtained by mixing dye-soda in certain proportions by the operator is added into these dyeing barrels. The main paint is sent to the system with the help of the pumps in the barrels and the painting process is carried out.

As can be understood from the way the current system works, a serious workforce is needed both in the preparation of the base dye mixture and in the filling of the barrels each time. In addition to this handicap of the system, the main dye obtained as a result of the dye-soda mixture starts to decompose after 3 hours and becomes darker than the desired color. This thickening paint becomes unusable and waste. Therefore, if the system is used in its current form, dye consumption will continue. One of the solutions may be to prepare a new dye-soda mixture every 3 hours and obtain the base dye. However, this method will also increase the workload significantly. For these reasons, the improvement of the system and the integration of dosing automation is necessary.

Figure 1. Existing dye system

3. DYE DOSING SYSTEM AND ITS USE

The dosage system used in paint preparation is the machines that perform the color mixture in the correct proportions without human factors, based on the prescriptions created. The main purpose of the dosing system is to eliminate the problems caused by the operator and standardizing the color mixing by automating it. Thus, both the color rendering process will take place in a certain order and the operator will not be exposed to chemicals.

In addition to these features, other advantages are presented as follows;

- Providing a mixture that will affect the chemical performance one to one by dosing from the right place,
- To be able to give the correct amount of chemicals required for the system by making the correct dosage,
- To prevent unnecessary and unconscious consumption that may arise from manual casting,
- To be able to calculate the daily chemical consumption and cost accurately,
- To adapt to the variability in dye consumption that may occur during the day by changing the chemical amount with the help of a dosage pump,
- To prevent the risks that may arise from manual casting in terms of Occupational Health and Safety before they occur [8].

The dyeing system has both advantages and disadvantages. It may take time for the personnel who will use the dosing system to have sufficient knowledge and experience. There may be a difference in tone between the color desired to be produced and the color obtained. When this situation is ignored, various problems may arise. For this reason, giving necessary training to the staff who will use the dosing system and informing them about the subject is of critical importance in order to prevent possible problems and prevent customer complaints.

In areas where chemical products affecting human health are used with paint, the preparation of the mixtures with the dosing system without hand touch will ensure the production of high quality, hygienic and high-efficiency products. This situation emphasizes the importance of the dosing system strongly. It significantly affects the quality of the factories and facilities where the system is used.

4. RECIPE PREPARATION AND COLOR PRODUCTION PROCESS

In the textile industry, catching the right color is very important to answer the customer orders correctly and to ensure the customer's satisfaction. Therefore, there are various methods for preparing the right dye prescriptions. Manufacturers can use the existing color archive, benefit from the international color catalogue Pantone. The color analysis method with a spectrophotometer or visual inspection method can be used as a result of the checks made in the light cabin based on the master received from the customer.

The method used in this study is the visual inspection method, led by an experienced operator. The operator creates a recipe after making the necessary examinations on the incoming master. According to this recipe, in which solid dyes are used, 5-liter pre-dye work is done. Pre-dye is mixed with 5 liters of soda in 1: 1 measure and the pH value are measured. The pH value is desired to be in the range of 10.5-11. If this interval is provided, the sample is dyed, and if the color passes the approval, 20 liters of paint is prepared and staining continues in this way until the end. The prepared 20-liter paint is mixed with 20-liter soda in a 1: 1 ratio and the main paint is obtained. The pH value of this mixture is measured again and if it is within the desired range, it is approved for dyeing.

5. MATERIAL AND METHOD

When the paint and chemical soda mix, the life of the paint lasts for a certain period and then changes color. When chemical soda is mixed with dyes, it changes the pH of the solution before it can last for a long time and causes the paint to deteriorate. In such a case, the solution must be emptied as waste before it is completely used up. Therefore, in the friction yarn dyeing process, excessive amounts of the mixture cannot be made and dye solutions that cannot be used are discarded.

For the continuation of production; During the continuous dye maker, dye changing element and changes, production loss occurs and unwanted waste amounts occur. In this study, a new dyeing machine has been designed with Alkali Dosing System. By eliminating the manual dye preparation process used before, the dye is prepared and painted automatically.

Thanks to this project, this stage has been eliminated by the operators engaged in the paint preparation process in the current painting type. Also, the paints that need to be changed after a certain period have been eliminated thanks to this project.

The deterioration time of the chemical, dye and soda mixture was determined by the test. The change in the first 5 hours is shown in Figure 2. Accordingly, the paint deteriorates at the end of the 4th hour. As a result of the surveys, they are the threads that come out as a result of the level 1, 2 and the maximum 3 hours acceptable as the Quality Assurance Unit. It was observed that the dyeing appeared in the following hours were not within the acceptable color limits.

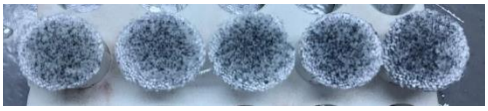

Figure 2. Change of chemical, dye and soda mixture in the first 5 hours

It is not possible to obtain mixtures in quantities of 2-3 grams with existing dosing pumps. This requires a very special design and computer control. New PLC software was created within the scope of the study.

Higher production amounts were obtained compared to the prepared solution. A new unit has been designed. Chemical soda and paint will not mix in the tanks in the designed unit and are kept in separate tanks. It makes the desired amount of solution dosing to the mixing tanks located under the machine with the valves placed at the bottom of the tanks. A system has been created to make dosing at the specified levels, and the deterioration of the main solution has been prevented since the soda mixture doses the solution at the required times in the system.

5.1. Modeling the System

The mechanical design of the dosing system was performed with the AutoCAD software. In addition, all the equipment used in the prototype was designed and assembled sequentially. The manufacturing process was carried out after the design work was completed.

The prototype is designed according to special dimensions in order to observe the desired results in the dosing system.

Volumetric measurements of the designed model are 60 liters for dye and soda tanks, 2.5 liters for standby containers and 5 liters for mixing containers.

The mechanical parts of the system are made of the chromium frame structure, pneumatic piston valves and chromium.

In addition, the mechanical parts of the system consist of paint and soda tank, waiting for the container, mixing container, electrical panel, level electrode, aquarium pump and water supply line. The drawing of the prototype system in AutoCAD is as shown in Figure 3. The parts of the system are explained in Table 1.

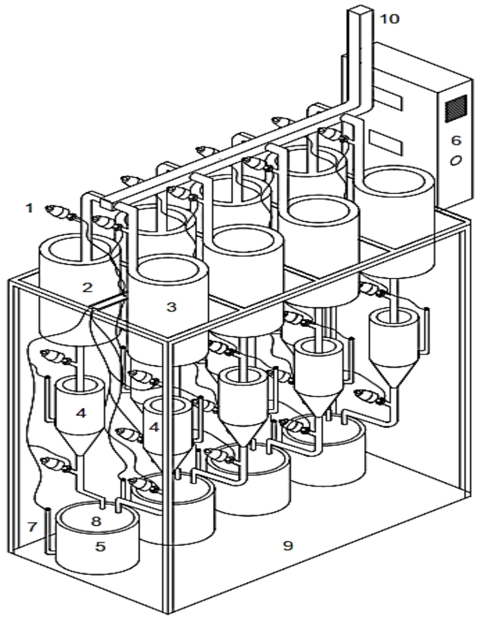

Figure 3. The designed model in AutoCAD

Table 1. The parts of the system the designed model in AutoCAD

Component No	Component Name	The function and technical characteristic of the components
1	Pneumatic Piston Valve	The pneumatic valve works by moving the single-acting piston with an air-controlled actuator. It is normally in the closed position. The piston moves upwards and the valve opens when air is supplied to the actuator. The valve is turned off by pushing the piston through the spring when the air is cut off. It is a Y-type valve in terms of shape.
2	Dye Tank	It will have a volume of approximately 60 liters and its raw material is chromium. It is the container where dyestuff and chemical mixtures wait.
3	Soda Tank	It will have a volume of approximately 60 liters and its raw material is chromium. There is only soda in the container.
4	The waiting container	It will have a volume of approximately 2.5 liters and its raw material is chromium. When the pneumatic valve is opened, the dye and soda will flow from the dye and soda tank to the waiting container, so it will stand ready.
5	Mixing container	It will have a volume of approximately 5 liters and its raw material is chromium. The mixtures in the waiting containers will flow into the mixing container by opening the pneumatic valve and will be ready for dyeing.
6	Electrical panel	Level electrodes enable the pneumatic valves to operate. There is a start-stop button.
7	The level electrode	Level electrodes are located in mixing and waiting container. It will help to fill the empty containers by opening the pneumatic valves when the mixture level decreases.
8	The aquarium pump	This pump will be located in the mixing container at the bottom. This pump provides the flow of the mixture ready for dyeing to the reservoirs on the machine.
9	The stand	It is the main body holding the system.
10	Water supply line	Required for washing dye and soda tanks.

5.2. Production of the Designed Model

Automation systems need a smoothly working mechanical structure to carry out the desired operations by performing the given commands. Therefore, one of the important points in the dosing system has been the design of mechanical parts. The tanks, waiting and mixing containers in the system are made of chromium. chromium material has high corrosion resistance, can be cleaned easily and has a much longer life than tanks made of other materials.

Level electrodes were used to warn the system when the paint and soda in the waiting containers and the mixture prepared in the mixture containers fall below a certain level and also it is made of chromium.

The pumps in the system have been chosen as an EHEIM brand for its smooth and trouble-free operation. A frame and a stand were produced to hold the whole system together. The system produced is shown in Figure 4 in its final form.

Figure 4. View of manufactured the dosing system

5.3. Electronic Parts of the System

5.3.1. PLC (Programmable Logic Controller) Device

PLC is a device used in programming complex systems thanks to its microprocessor, which has many inputs and outputs. PLCs are like a computer that operates according to the systems it will control, without a monitor and keyboard. PLC programs scan the input information in the order of milliseconds and work with the appropriate output information close to real-time, responding [9]. The working steps are shown in Table 1 and its general structure is shown in Figure 5.

Scan time = The time to perform step 1 + The time to perform step 2 + The time to perform step 3 [10].

PLC has a shorter setup and commissioning time compared to other connected systems. In addition, although the PLC system is likened to a computer system, it has certain hardware suitable for industrial control;

Safe, unaffected by noise Modular plug-in structure, units can be easily changed or added (For example, Input/output) Standard input/output connections and signal levels Easy to understand programming language On-site programming and reprogramming easily Communication with other PLCs, computers and smart devices Superior in both cost and space compared to relay and solid-state logic systems [11].

To realize this dosing automation, Panasonic FP0R F32 32K shown in Figure 6 was preferred. Its task is to monitor and control the system from the HDMI screen. It has a simple command processing time of 0.08 microseconds. Memory expanding up to 32 K Steps is available.

Table 2. PLC operation steps

1	Testing the login status	First of all, PLC checks the open/closed status of each switch or sensor in the system and observes whether it is active or not. It stores the obtained information in its memory for the next step.
2	Program execution	The program loaded into the PLC at this step performs the data stored in its memory in the previous step. The action performed can enable certain outputs or save the results for recall in the next step.
3	Checking and correcting the output status	Finally, the PLC checks the output signals and adjusts them as needed. The changes are made according to the input state read in the first step and the result of the program execution in the second step. After executing the third step, the PLC returns to the beginning of the loop and repeats these steps continuously.

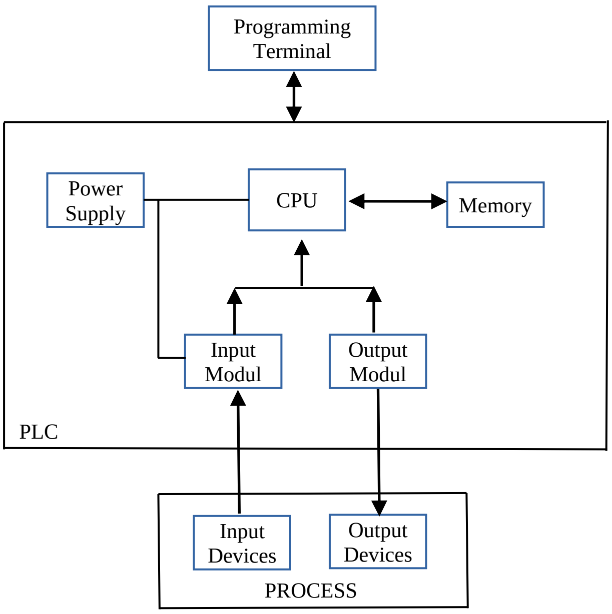

Figure 5. PLC Structure

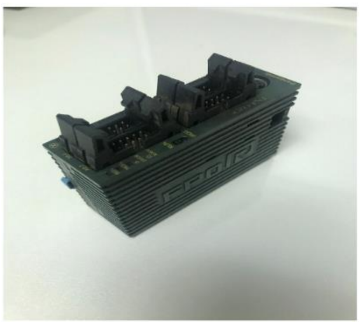

Figure 6. Panasonic FP0R F32 32K model PLC used in the system

During the programming of the PLC system, it is necessary to have full knowledge of the control circuits. PLC system is the most common Ladder programming language among many programming languages it has.

It has a shape similar to the electrical scheme of control circuits in the ladder programming language. Just like in real circuits, contacts and outputs representing relays are used. Unlike ladder programming, control giants, the preparation of the circuits is done on the horizontal axis. It is based on the principle of taking energy from the left side and transferring it to the outlet on the right [2].

In Figure 7, a part of the code consisting of 260 lines written as Ladder diagram for the dosing system is shown.

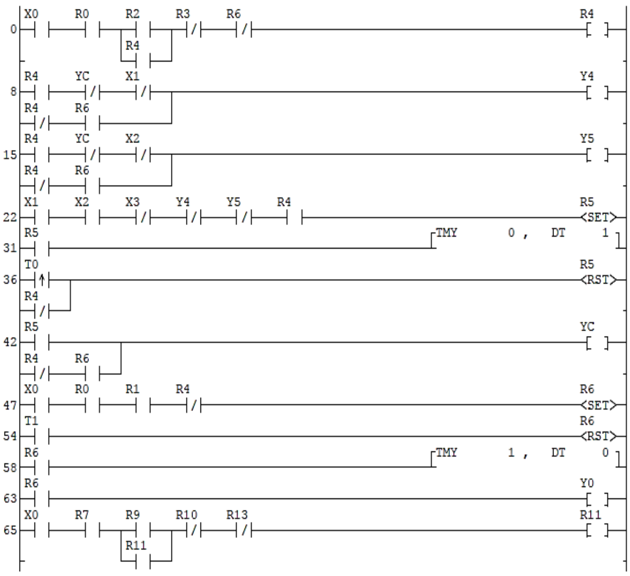

Figure 7. LADDER diagram

The screen becomes ready for use. After the dye and soda tanks are filled with the help of the operator, the stations that will operate from the Station On/Off command on the screen are switched to the Station On position as in Figure 8 and the system is started by pressing the start command. First, dye and soda waiting containers of 2.5 liters are filled. Then the dye and soda are transferred to the 5 liters mixing container. The refilling time of the waiting container and the mixing container is determined by a warning given by the electrode level bar. Since the densities of soda and dye are different from each other, the time filling the mixture containers and waiting containers are determined based on density of dye in system (approximately 20 seconds).

After the painting process is completed, make sure that the Emergency Stop button is not pressed on the screen for cleaning. As in Figure 9, the station must be Station On, the Washing On command must be selected and the Start button must be pressed. While the washing process for the dye tank, dye waiting container and mixing containers are applied after each dyeing, it is done in three-month periods for soda. Because soda is used constantly for all dye types.

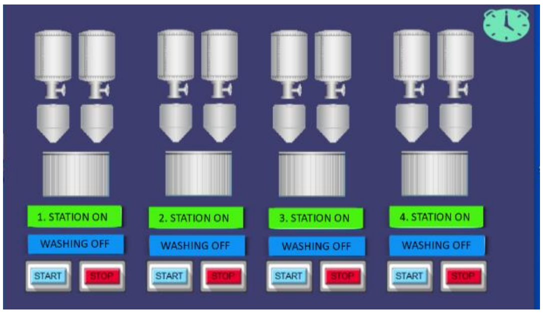

Figure 8. HMI screen during the dyeing process

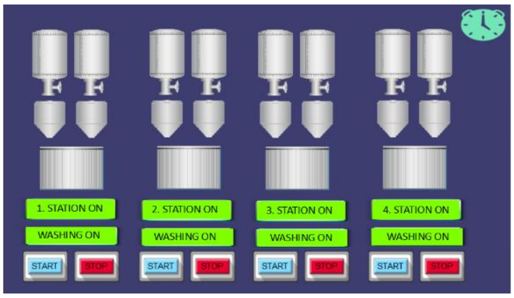

Figure 9. HMI screen during the washing process

The flow diagram of the dyeing process performed with the dosing process is shown in Figure 10.

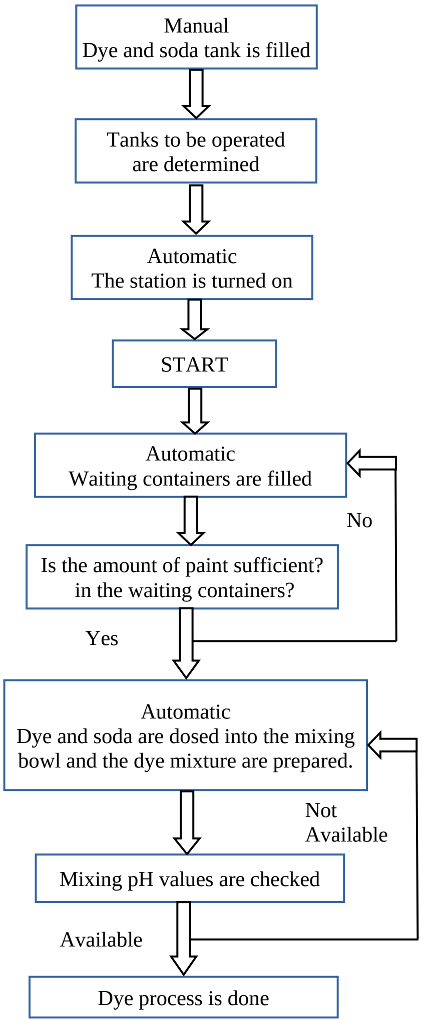

Figure 10. The flow diagram of the dyeing process

6. CONCLUSIONS

Since the deterioration of the dyes during operation causes the colors and the image to deteriorate, smooth progress cannot be achieved. Thanks to this study, the lifetime of the dye solution and soda solution has increased since they are not mixed. The increase in the service life of chemical soda and dye reduces the margin of error in production and reduces the cost. The deterioration experienced after the reaction of the chemical soda with the dye at the end of about 3 hours under normal operating conditions and the separation of the chemical soda and dye in the tanks on the machine, thanks to the design made, solved the problem of deterioration. In the new proposed system, the amount of solution separated as waste has been reduced. Thus, ecological was provided beneficial [22]. Therefore, the solution in the new system has a longer life. This situation has reduced cost and environmental pollution.

In addition, the ecological benefit it provides also affects the use of water, and it has also provided significant benefits in this area [23]. Dosing has been controlled by making new software studies in the system. Thanks to the level sensors to be placed in the containers containing chemical soda and dye solutions coming out of the dosing valves under the machine, the dosing level has become controllable. With the help of the HMI control screen placed on the machine, the operator and shift supervisors can instantly see the dye and chemical soda levels on the screen. In case of a decrease in dye and chemical soda, it is ensured that the pressure transmitters that we use to detect the level in the tanks receive instant data on the screen and alert the operators in case the levels decrease.

Thanks to this study, the deterioration of the prepared paint at the end of 3 hours, the operator's continuous preparation of 20 liters of dye-soda mixture and the consumption of extra prepared or spoiled paint have been prevented.

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BIOGRAPHIES

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