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Temperature and Level Controller for Fingerling Pond

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Abstract

In this document, the design of a temperature and level controller in a fingerling pond is presented, which has an automatic system that provides food to these fingerling in the pond by stipulated times according to the schedule, where depending on the species of fingerling has certain characteristics to develop in their environment. The system has a main power board supported by an emergency board (UPS), which controls the actuators of the system by means of a PLC, taking into account that the water must have a circulation cycle due to deposited feces and its alkalinity, therefore, an opening of the water inlet and outlet valve must be made, so that it can be treated by means of filters and can return to the environment or, if not, be reused again in the system.

Keywords. Fingerlings, controller, temperature, level, variables.

INTRODUCTION

The farming of animal and vegetable species that fulfill all or part of their life cycle in the water is an activity that has been practiced for more than 2000 years, the first records date back to 500 BC in China, where Fan-Li developed the first fish farming treaty based on the culture of the carp, while the Romans did it in oyster cultures extracting specimens of small size from nature for their fattening. In the fourteenth century, French monks developed the cultivation of rainbow trout. At the end of the 18th century, trout and salmon eggs were fertilized artificially, from the development of a technique that a century later contributed to the repopulation with juveniles of these species [1].

In the 20th century, towards the end of the 1940s, the countries of the Indo-Pacific region, Taiwan and the Philippines, practiced the aquaculture of numerous species such as carp, tilapia and bivalve mollusks intensively, with more advanced technologies, allowing the mass commercialization of production, covering the demand for protein in their local markets. Fish farming (fish culture) was and continues to be the most significant activity within the volume of aquaculture production. Its boom is reached from the decades of 1960 and 1970, years in which a great scientific and technological development was achieved. [2]

The per capita supply of fish has reached its historic peak in 2008, which suggests the size of this sector and its importance in the income of subsistence and small-scale fishermen, without forgetting that fish is a source of high quality animal proteins and, what is more important, it is economical.

Aquaculture, which is the breeding or cultivation of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants, in a controlled environment avoiding pernicious effects on nature and applying techniques aimed at increasing, beyond the natural capabilities of the environment, the production of the organisms in question. These systems have already been studied at the research level, in open and closed environments, as discussed in [3].

Not only traditional systems such as agriculture are objects of improvements in production, by engineering techniques, as discussed in [4]. In this way, the present work presents the design of a monitoring system for the feeding of fingerlings, which seeks to obtain a low mortality rate, increase production and provide support tools to control pond conditions as a system for the technification of aquaculture.

Different control algorithms have been implemented for various types of crops in order to improve the efficiency of this, as discussed in [5]. However, for aquaponic systems they have not been addressed, which is why a base algorithm of proportional, integral and derivative control (PID) is applied in this field.

Next, the article is divided into three sections, methodology, results and conclusions.

METHODOLOGY

The following generalities related to development are defined below, based on an aquaculture system:

Types of ponds: There are 4 types of ponds which are explained below:

Tamped ponds: These ponds use the same soil, nothing is added except grass to have better grip. In some cases some stones are added which are tamped against the bottom. This type of ponds are used in large farms. Many times, these ponds are built in natural wells of the place which is almost always filled with the rainwater itself plus water from tankers.

Prefabricated ponds: They are like pools, you can buy them in aquariums and some pool factories also have some designs.

When selecting the prefabricated pond, pay close attention to the correct depth. They have different measurements and sizes. The small ones are very used in winter gardens.

Canvas ponds: Using special plastic tarpaulin a very natural touch is achieved in the pond. The canvases allow greater maneuverability in the design stage of the pond and allow to secure the pond without much labor. The important thing in the canvas is the quality, there is no need to save quality at the time of purchase, for instance, imagine emptying a pond because the canvas was cut because of poor quality. [6]

The canvases must be of high quality flexible EPDM, with a thickness of 0.8mm minimum. They must be resistant to ultraviolet rays. They must be resistant to frost and heat. There will be no tarpaulin brands (this is not a commercial site) but nowadays all the tarpaulins of aquarium product brands are very good and of similar qualities, their differences are in size and price (the brand). These canvases have guarantees from their manufacturers. [7]

Another important aspect is the quality of water, which includes all the physical, chemical and biological variables that influence the production of aquatic species.

The management practices of fish and shrimp culture have the objective of maintaining the adequate chemical and biological conditions in the environment, for which in an aquaponic system an automation of this is indispensable, in order to seek to improve the autonomous productivity of the same, as it is presented in terrestrial cultivation systems, such as the development illustrated in [8].

On the other hand, an automated system is made up of elements or instruments, which are used to measure physical variables, exercise control actions and transmit signals. In all processes it is absolutely necessary to control and maintain certain quantities constant. [9]

The dictionary of the Royal Spanish Academy defines “Automática” (Automation) as the discipline that deals with methods and procedures whose purpose is the replacement of the human operator by an artificial operator in the execution of a previously programmed physical or mental task. [10]

For the general development of the system it was decided to use a methodology of evolutionary type, divided into three phases, which are: Analysis, design and tests. The methodology also allows to return to an earlier phase if any inconsistency or error is detected, or if it is wanted to improve some aspect of the system.

The production phases of the aquaculture system are presented in figure 1.

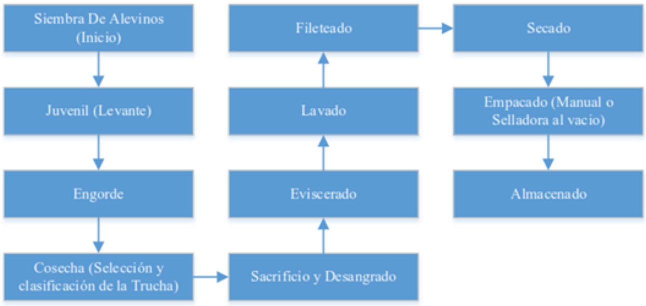

Figure 1. Production phases.

Initially, information gathering was done, which covered all the topics related to the theoretical foundation necessary for the development of the project, in this way there is a starting point to move on to the next stage. Next, the general system, the storage tank system used, the fish feeding system and the controller design are described.

A. GENERAL SYSTEM

To begin, the process of the monitoring system for feed of fingerlings in prefabricated pond is described below, as can be seen in figure 2. The fingerlings processing plant has a deep well, a water extraction pump from the POZ-001 well, two water storage tanks, a TK-101 tank inlet solenoid valve, a food distributor motor, a TK-101 tank outlet solenoid valve, a contaminant separator, an active carbon filter, a TK-102 tank water pump.

Figure 2. Process diagram

Based on the above, figure 3 shows the functions that the PLC will control, in which it begins with the regulation of the level of the tanks TK-100A/B, also with the control of the valves of opening both of entrance and exit of the tank TK-101, the activation of the illumination, the activation of the motor of distribution of food, the activation of the resistance and the activation of the engine of oxygenation.

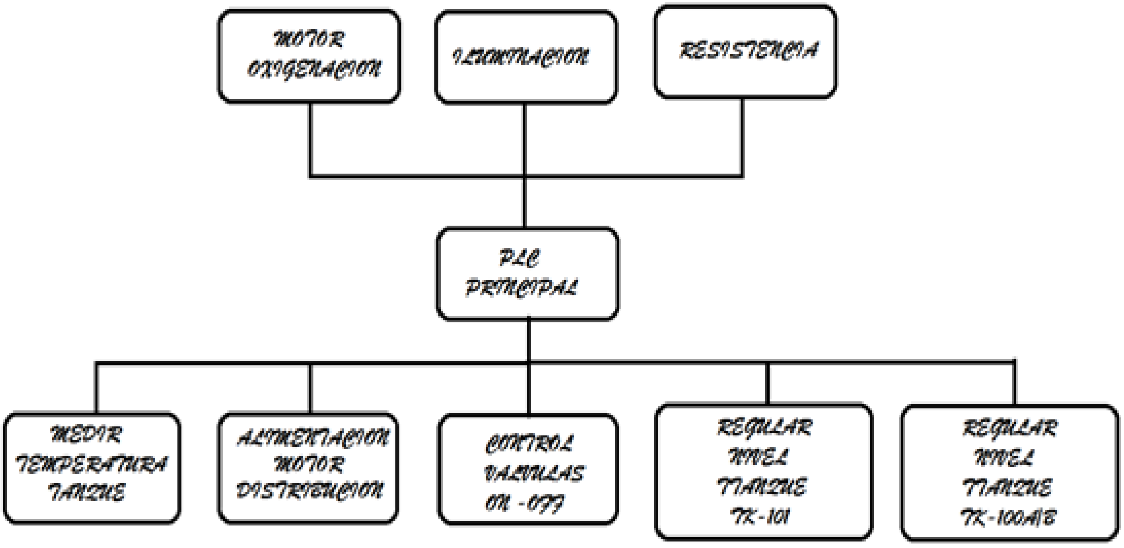

Figure 3. Diagram of operation

Figure 3 shows the top view of the monitoring system for feeding fingerlings, whose process begins with the extraction of water from the deep well POZ-001, by means of a motor pump PLA-P-PBB-001, which is activated when the high level switch of the well is closed and the low level switch of the storage tanks TK-101A/B is open, and deactivated when the high level switch of the well or the high level switch of tanks TK-101A/B is closed. Once the tank TK-101A/B is full, the level control valve LCV-001 is activated, that allows the water to pass through the OXI-001 waterfall-type oxygenator and reaching the TK-101 tank, this valve will be active until the tank's low and high level switch are closed.

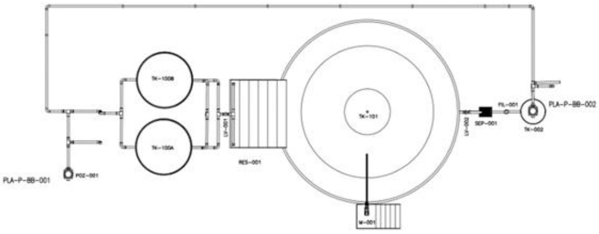

Figure 4. Fingerlings process plant top view.

When the high level switch of tank TK-101 is closed, it will activate the oxygenation motor and the food distribution motor, which will have programmed activation and deactivation cycles.

On the other hand the system in a certain time will make a change of water, with the activation of the cleaning switch, this will activate the level control valve LCV-002, responsible for extracting water to a sediment separator, when the water passes through the sediment separator will continue to the active carbon filter, after which it will reach the tank TK-102 which will store this water.

When the high level switch of tank TK-102 is closed and the level switches of tanks TK-100 A / B are open and the PLC is in recirculation mode, pump PLA-P-BB-002 will be activated supplying water to tanks TK-101 A/B, until the high level switches of tanks TK-100 A/B get closed.

B. STORAGE TANKS

With respect to the storage tanks TK-101A/B (figure 4), the calculations are then made to determine their volume and thus establish the amount of water it will contain, taking into account equation 1 and the following information:

Radius (r)=2130mm

Height (h)=600mm

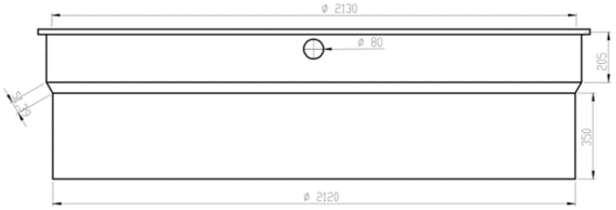

Figure 5. Storage tank TK-100 A/B.

$$Vtank = \pi r^2 h \quad (1)$$

Obtaining:

$$Vtank = \pi(2130mm)^2(600mm)Vtank = 8551{,}6\ liters$$

The system contains two tanks, therefore, the total volume is:

$$Vtanks = 17103{,}2\ liters$$

In the same way, the volume of tank TK10 is calculated, taking into account that it is carried out in parts, according to the geometry of each area (see Figure 6), by means of equation 1.

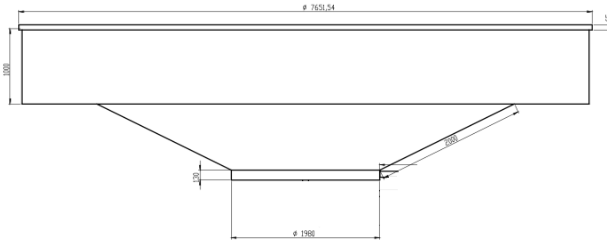

Figure 6. Storage tank TK-101.

First Part

Radius(r)=3000mm

Height (h)=1000mm

$$Vtank = \pi(3000mm)^2(1000mm)$$

$$Vtank = 28273{,}5 \text{ liters}$$

Second Part

Radius(r)=1980mm

Height (h)=763.7mm

$$Vtanqk = \pi(1980mm)^2(763.7mm)$$

$$\text{Vtank} = 9405{,}68 \text{ liters}$$

Third Part

For this part, the volume of a truncated cone is taken into account, using equation 2, with the following data:

Height(h):800mm

Larger base radius (R):2800mm

Minor base radius (r):1980mm

$$Volume = \frac{\pi.h}{3}(R^2 + r^2 + R.r) \qquad (2)$$

$$Volume = [(2800mm)^2 + (1980mm)^2 + ((2800mm)(1980mm))]$$

$$Volume = 14496{,}576\ liters$$

Fourth Part

Corresponds to the total sum of the results.

$$\text{Total Volume} = 28273{,}5\text{liters} + 9405{,}68\text{liters} + 14496{,}576\text{liters}$$

$$\text{Total Volume} = 52175{,}756 \text{ liters}$$

In this way it is established that the main tank, which will house the fingerlings, has a total volume of 52175.6 liters, therefore it is required that the tanks TK-100A/B provide them three times their capacity.

C. FISH FEEDING

With regard to the feeding of fish, reference is made to table 1, in which fish are considered between 200 and 400 grams.

Table 1. Fish feeding

PESO DEL PEZ EN GRAMOS		
°C Agua	200-300	300-400
21	1.2%	1.1%
22	1.3%	1.1%
23	1.4%	1.2%
24	1.4%	1.3%
25	1.5%	1.3%
26	1.5%	1.4%
27	1.6%	1.4%
FRECUENCIA DE SUMINISTRO		
Veces/Día	4	4
DÍAS APROXIMADOS DE CADA CICLO		
Días	55	45

In the system, the information provided regarding the feed of the fingerlings is taken into account, since the amount of food that will be supplied by the automatic system will depend on this, especially for the present work that considers red tilapia.

One of the aspects to keep in mind is that the system will deliver the food in small rations, looking for fish to take the food from the surface, avoiding in addition that part of the food falls to the bottom of the tank, where it will be lost because the fish will not eat it once it reaches the bottom of the prefabricated pond.

D. CONTROLLER DESIGN

The modeling of the plant for the temperature controller using ZIEGLER-NICHOLS tuning is described below, whereby the plant can be described from the transfer function described by equation (3).

$$G(s) = \frac{Ke^{-Ʈs}}{1 + Ls} \qquad (3)$$

Where the coefficients K, Ʈ and L are obtained from the response of the open loop system to a step input (figure 7).

Starting from the stabilized system in y (t) = y0 for u (t) = u0, a step input from u0 to u1 is applied (the jump must be between 10% and 20% of the nominal value) and the response of the output is recorded until it stabilizes at the new operating point.

The parameters can be obtained from the response shown in Figure 7, by equation 4, 5 and 6:

$$\tau = t_1 - t_0 \quad (4)$$

$$L = t_2 - t_1 \quad (5)$$

$$K = \frac{y_1 - y_0}{u_1 - u_0} \quad (6)$$

Based on the Ziegler-Nichols tables (table 2), the relationship of these coefficients with the parameters of the Controller is:

Table 2. Tuning of PID controllers

Tipo	**Kp**	**Ti**	**Td**
P	T/L	INF	0
PI	0.9(T/L)	L/0.3	0
PID	1.2(T/L)	2L	0.5L

Once the procedure has been carried out to the plant, the response shown in Figure 7 is obtained, finding there the values of the constants with which the system will be designed.

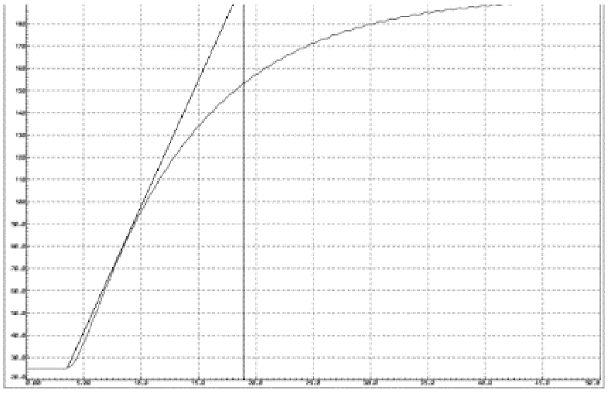

Figure 7. System behavior

Where the parameters of equation 3 are:

$$K_0 = 83$$

$$t0 = 1.22$$

$$y0 = 15.17$$

The values obtained for the controller through table 2 are:

$$kp = 0.18$$

$$\mathrm{Td} = 2.43$$

$$\mathrm{Ti} = 0.62$$

RESULTS

From the obtained values, calculations are made to model the controller and test it through MATLAB to observe its behavior. Subsequently, the proportional gain was adjusted to Kp=0.76 to set the desired behavior, decreasing the maximum overshoot, as shown in figure 8. With the defined gains and the calculated system behavior, the PID controller is implemented with the Programmable Logic Controller (PLC).

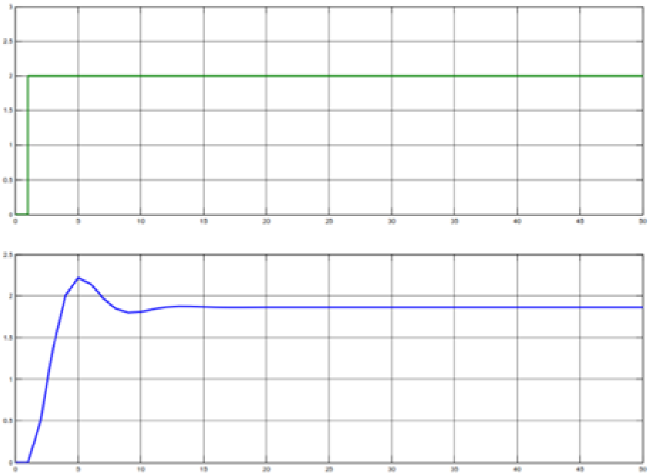

Figure 8. Simulation of the system response.

PLC simulation

To carry out the Ladder programming in the TIA PORTAL V13 software, the installation of the PLC device and the PC system_1 connected by the network PN/IE_1 is taken into consideration (see figure 9).

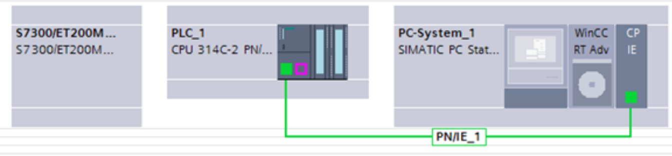

Figure 9. Control architecture.

The programming is based on the C&E Matrix document and the plans and PL-PRO-003-001. The main program and subprograms are created.

In the process window, it can be observed the activation and deactivation of the different variables, also the activation of the equipment and levels that these tanks handle (See figure 10).

Start and stop of the Main system

The system has a process start button, which is a conditional for the start of the subprograms of the main program and that can be reset by the stop button, which when activated creates an emergency stop for all systems and puts the start button in the reset state.

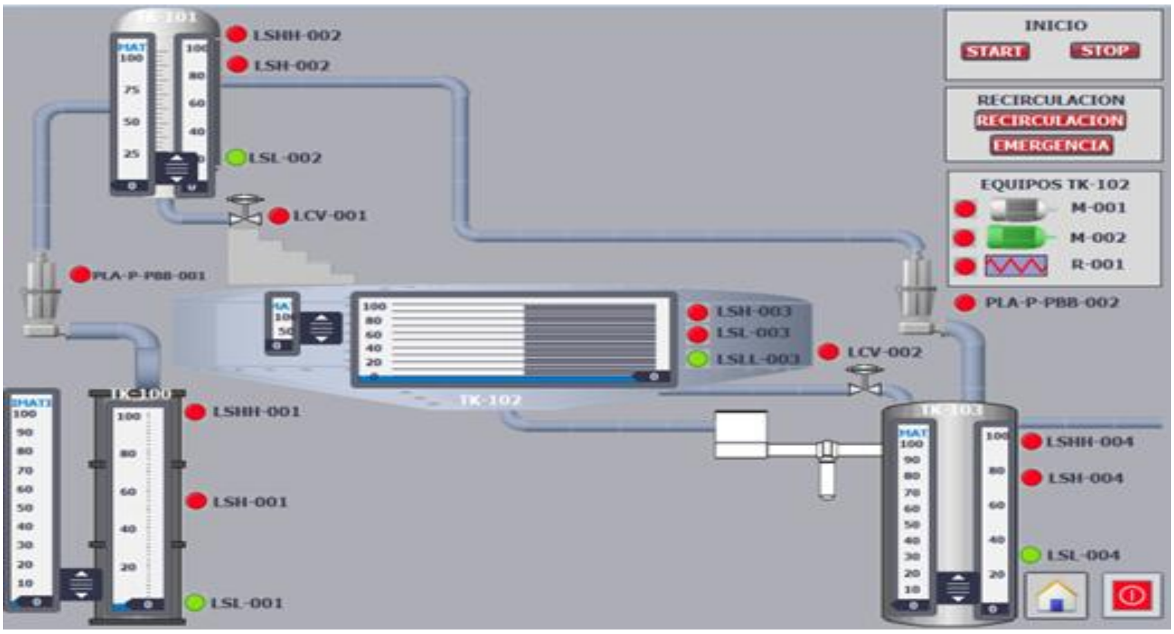

Figure 10. Process screen.

Water storage system

The system begins with the filling of the POZ-100 deep well. When the high level LSH-001/LSHH-001 of the well and the low level sensor LSL-002 of the tank TK-100 are active, it activates the pump PLA-P-BB-001; this pump remains active until the level sensors LSH-002/LSHH-002 are activated and the pump is switched off, also sequentially activating the LCV-001 control valve when the LSLL-003 level sensors are active and the sensors LSH-002 and LSHH-002 are deactivated.

This cycle of activating and deactivating the pump PLA-P-PBB-001 and the level control valve LCV-001 is performed until the tank TK-101 is completely full by activating the level sensors LSL-003 and LSH-003. When these sensors are activated, the counters of the M-001 power motor and the M-002 oxygen motor will begin to operate, which will provide the oxygenation and feeding of the fingerlings at certain times. On the other hand, there is a PT100 temperature sensor which senses the temperature of the water at all times and delivers this signal to the PID controller to carry out the control process through a heater.

This stored water of the TK-101 must be contained a certain amount of time and then it must be changed, due to the turbidity present by the defecations of the fish and the amount of cyanide in the water produced by the exchange of oxygen from the fish. Due to this, there is a water recirculation button, which is activated according to a programming of the timers or manually.

When the recirculation button is activated, it produces a stop status for the PLA-P-PBB-001 pump of the level control valve LCV-001, and the level control valve LCV-002 is activated. Taking into account that the LSL-003 or LSH-003 sensors are active, this will remain open until the low level sensor LSLL-003 is activated, which will cause the level control valve LCV-002 to close and restart the recirculation button, so that the system returns to the water storage state.

The water that leaves the tank TK-101 goes through a sediment filter and then goes through an active carbon filter, in order to return the water in the best optimal conditions and take it to the tank TK-102 which stores liquid up to a certain limit and after that the water is sent to the nearest point of a tributary.

RECOMMENDATIONS

After analyzing the data of the project implemented, it is concluded the importance of using a water pH measurement system, in such a way that the conditions of the tanks can be improved.

An expansion of the plant could be made in parallel, since the programmable controller has the capacity to recognize several signals.

It is important that an eventual implementation of the plant takes place in a site that is rich in underground water sources, so that the costs of implementing the well are not far-reaching.

CONCLUSIONS

Monitoring and controlling the environment of the fingerlings allows them to improve their maturation stage in such a way that the production times decrease considerably and thus greater productivity is achieved.

Simulation tools are important for programming in general, because it provides the possibility to see the failures that are presented and analyze the best option to correct them, so that the implementation is developed with the best conditions.

The installation costs of the plant will depend on the geographical location and depth of the deep well.

The response times of the automated system allow the environmental conditions to stabilize in a shorter time before any disturbance, thus achieving that the conditions of temperature and level are in optimal conditions for the feeding process of fingerlings.

Properly establish the feeding times, in addition to the amount needed depending on the state of the fingerlings, allows a considerable saving of food since small quantities will be provided for the fingerlings to consume it from the surface, since in case of reaching the bottom of the pond it will not be consumed, therefore it would be wasted.

By means of these automation systems, it is possible to reduce the times that the personnel interact with the different equipment and elements, thus reducing the accident rate.

To exercise a better factor of cleaning and disinfecting the tanks, it is required that there be more than one tank of process.

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