International Journal on Robotics, Automation and Sciences

Automatic Filling Machine for Metracide 1 Liter Product Variant at Global Medipro Investama LLC

Muhammad Raihan Arrasyid and Iksan Bukhori*

***Abstract* – Global Medipro Investama LLC previously used a CNC liquid filling machine to fill the Metracide 1-liter variant product into bottles. This machine very often produces output that was not in accordance with the company's specifications. Based on data from 3 production batches, the average yield rate score obtained was 51.96%. The low-yield rate score indicates that the production process is ineffective and inefficient because of the unstable filling process. This research aims to design and manufacture an automatic filling machine with four nozzles and use PLC as its controller so that the production process becomes more effective and efficient by increasing the rated yield and quantity of output and speeding up the cycle time by eliminating the manual weighing process using loadcell and weighing indicator. Based on data from 3 batches of production using the new machine, the average yield rate score obtained was 98.51%, which increased by 46.3%, significantly more than the old machine of 51.96%. The machine also managed to speed up the production cycle time at the filling station. To produce 495 bottles only takes 33 minutes, making the production process 75.49% faster than the old machine of 134 minutes. The increase in output yield and quantity, and the reduction in cycle time show that the production process has become more efficient and effective.**

Keywords—Automatic Filling Machine, Programmable Logic Controller (PLC), Siemens PLC S7-300, Metracide 1 Liter, Yield Rate.

I. Introduction

Global Medipro Investama LLC is a company that produces high-level disinfectants for the Central Supply Sterilization Department (CSSD) needs in hospitals. There are two types of products produced by Global Medipro Investama LLC, namely liquid-based products, and powder-based products, where the most widely produced product is a liquid-based product called Metracide 1 liter variant.

Global Medipro Investama LLC aims to have an effective and efficient production process to minimize losses in the production process. To improve the effectiveness and efficiency of the production process, this year Global Medipro Investama LLC began to make improvements to the liquid production line, precisely at the product filling station for the 1-liter Metracide variant product. The obstacles found at this liquid product filling station cause the production process to be inefficient and ineffective due to poor machine performance.

As shown in Figure 1, Global Medipro Investama LLC uses a CNC liquid filling machine to accurately fill liquid products into bottles. However, this machine is inconsistent in the amount of liquid filled into the bottles, causing the output not to match the company standard which accumulatively may cause what is called natural production loss due to low yield rate. To minimize this loss, operators must manually weigh each bottle and perform rework, slowing down the production cycle time and causing time loss. This

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International Journal on Robotics, Automation and Sciences (2024) 6, 2:16-24
https://doi.org/10.33093/ijoras.2024.6.2.3
Manuscript received: 8 Apr 2024 | Revised: 15 May 2024 | Accepted: 4 July 2024 | Published: 30 Sep 2024

Published by MMU PRESS. URL: http://journals.mmupress.com/ijoras

manual labor may reduce the efficiency of the work and very costly. This is shown in the fact that the maximum output per batch was only 490 bottles, while the target was 500 bottles, resulting in a natural production loss of 10 bottles per batch.

FIGURE 1. CNC filling machine (old filling machine).

This research aims to design and manufacture an automatic filling machine with 4 nozzles that uses the Siemens S7-300 PLC as a controller with features that can speed up production cycle times, produce output that meets the standards set for the product, and increase the amount of output so that the production process becomes more effective and efficient.

Thus, this research is expected to provide improvement for Global Medipro Investama LLC increases production efficiency and effectiveness, especially in the liquid production line for the 1-liter variant of the Metracide product.

II. LITERATURE STUDY

A. Literature Review

Several basic studies were conducted to find ideas or inspiration in similar studies that other researchers had previously worked on (see Table 1). Rafid Salih et al. [1] made a liquid filling machine using Allen Bradley Programmable Logic Controller (PLC). They only used proximity sensor to detect empty bottle on the conveyor but no sensor to detect liquid level in the bottle. A solenoid valve is used to regulate the flow of the liquid itself into the bottle.

Betancourt, et al. [2] designed an automatic gallon filling machine for soap liquid. The filling process is automatically stopped based on sensor reading, however there is no weighing process involved.

Shivaani Varsha, et al. [3] designed an IoT-based smart ratio dispensing system using ESP8266 NodeMCU as a microcontroller, 5kg Loadcell, Firebase as a database, and IFTTT acts as a liaison between applications and devices.

Based on research that has been done before, the author wants to create an Automatic Filling Machine with 4 nozzles using the Siemens S7-300 PLC as a controller and using MYPIN to determine the liquid volume and read the reading from the Loadcell has not been implemented by previous researchers. The entire comparison with existing research can be observed in Table 1.

This Automatic Filling Machine proposed in this paper is designed to increase effectiveness and efficiency in the process of production of the Metracide 1 liter variant. This machine uses a Siemens S7-300 315-2 DP Programmable Logic Controller (PLC) because the user is familiar with PLC from other brands. Also, the machine does not use a microcontroller because is not industry standard.

TABLE 1. Research comparison.

Project Title and Year of Publication	Author	System and features
Designing a PLC-based Bottle Filling Machine with ConveyorSystem and Reduced Filling Time Using Ladder Logic	Rafid Salih, et al.	1. Allen Bradley PLC as controller 2. Proximity sensor to detect bottle on conveyor 3. Fluid is flown into the bottle for predetermined length of time
Automatic Gallon Filling System Controlled by Programmable Logic Controller-PLC	Faiber Robayo Betancourt, José Salgado Patrón and Johan Julián Molina Mosquera	1. Siemens S7-1200 PLC as controller 2. SHAR2YOA21 sensor to detect soap liquid level 3. LJC18A3-BZ-AX proximity sensor to detect empty gallon on the conveyor
Design of IoT-based smart Ration Dispensing System Using Loadcell Feedback to prevent Ration Fraudulence	Shivaani Varsha, et al.	1. ESP8266 NodeMCU as microcontroller 2. Loadcell to weigh the product's mass 3. Servo motor to control the flow
Automatic Filling Machine for Metracide 1 liter product variant at Global Medipro Investama. LLC	Muhammad Raihan Arrasyid and Iksan Bukhori	1. Siemens S7-300 PLC as controller 2. Loadcell to weigh the actual mass of the product that fills the container. 3. MYPIN Weighing Indicator to display loadcell readings and to set charging set points. 4. Solenoid Valve to open and close the liquid product flow. 5. Photoelectric sensor to detect the bottle at each nozzle.

This machine uses a Photoelectric sensor to detect bottles because this sensor can withstand disturbances that can interfere with sensor readings, such as temperature on IR sensors and sound reflections on ultrasonic sensors. To open and close the flow of liquid products, this machine uses a Solenoid valve so that it can be operated automatically.

To read and control the filling process, this machine uses a loadcell so that the filling process will be more accurate because the filling process will stop depending on the actual reading of the loadcell and the production process will be much faster because the weighing process as carried out in the production process using the old machine has been eliminated.

B. Theoretical Basis

Product Specification

In the 1-liter Metracide variant production process, there is a tolerance range for filling the amount of liquid that has been determined by Global Medipro Investama LLC, starting from 1000 grams to 1020 grams. As shown in Table 2, If the liquid filled into the bottle is less than 1000 grams or more than 1020 grams, the output is considered a Not Good Product (NG). Otherwise, if the liquid filled into the bottle is within that range, the output is considered as a Good Product.

TABLE 2. Metracide 1-liter variant product specification.

Filled product	Status Output
X >1020 gram	Not Good (NG)
1000 >= X >= 1020 gram	Good
X < 1000 gram	Not Good (NG)

Yield Rate

Yield Rate is the ratio of output that meets the standards or product specifications set by the company compared to the total output or products in a production batch ([4], [5], [6], [7], [8], [9], [10], [11]). Yield rate can help to measure or find out how well the performance of the machine is used in producing products that meet the standards. The yield rate can be calculated according to (1).

$$Yield\ Rate = \left(\frac{Good\ Pieces}{Total\ Output}\right) \tag{1}$$

Cycle Time

Cycle Time is the time required to produce one output or product from one production process cycle in 1 batch ([12], [13], [14]). By knowing how long the cycle time required in a production, the effectiveness and efficiency of the process can be analyzed. Cycle time on one batch of production can be calculated according to (2).

$$Cycle\ Time = \left(\frac{Production\ Time}{Total\ Output}\right) \tag{2}$$

III. RESEARCH METHOD

A. Hardware Design

Block Diagram

Block diagrams provide an easy way of graphically illustrating the operational workflow from a given system. The system's components are depicted through blocks that are linked together by arrowed lines. The block diagram's utilization simplifies the analysis and understanding of the system's process flow.

Figure 2 is a Block Diagram for this Automatic Filling Machine. The following is an explanation of the function of the blocks contained in the block diagram as shown in Figure 2.

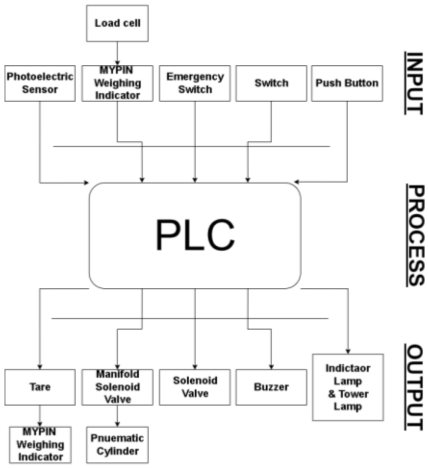

FIGURE 2. Automatic filling machine block diagram.

This machine uses several types of inputs to operate its functions. First, there are four types of push buttons that generate input signals. These buttons are processed by a programmable logic controller (PLC) to execute specific commands or functions. PLC is chosen instead of microcontroller such as Arduino because even though Arduino has been very successful in many automation systems ([15], [16], [17], [18]), PLC is deemed to be better suited for the industrial application, since it satisfies industry standard better.

In addition to push buttons, this machine also uses two types of switches. First, the "ON/OFF" switch is used to turn the nozzle unit on or off. Second, the "Manual/Auto" mode switch allows users to select the operating mode of the machine.

The emergency switch is also an important component in this system. This switch is in the form of a button and is used to signal the PLC to stop all machine operations in emergency situations, such as work errors or problems that threaten the safety of the user.

Furthermore, there is a loadcell and a MYPIN weighing indicator used to measure the mass of objects and display the results. During the filling process, when the liquid reaches the set point, MYPIN sends a signal to the PLC to stop the process.

This machine uses a Programmable Logic Controller (PLC) to process input signals obtained from input devices such as Push Buttons, Switches, Emergency Switches, MYPIN Weighing Indicators, and Photoelectric Sensors. Then the PLC will send commands or instructions in the form of output signals to each output device, such as an Indicator Lamp, Tower Lamp, Buzzer, Solenoid Valve, Manifold Solenoid Valve, and Tare on the MYPIN Weighing Indicator so that the system will run according to its design.

The output of this machine includes several major components. First, there is a liquid pump that uses a centrifugal pump to drain the liquid product from the mixing tank during the production process. Next, there are indicator lights that provide visual information about the condition of the machine, such as a green light to signify various conditions such as bottle detection, the status of the "ON/OFF" switch, the "Start" and "Auto Start" buttons, and the "Reset" button. In addition, there is a red light on the "Stop" button that lights up when the button is pressed to stop the process, and an amber light on the "Tara and TestPos" button that lights up during the "Tara" procedure at the beginning of the product filling process.

The Tower light is an additional electronic device that provides further visual information about the condition of the machine, using three different colors. Red indicates the machine is "OFF", yellow indicates the "Test and Tare" feature is in progress, and green indicates the machine is "ON" and ready to operate.

In addition to the lights, there is a buzzer that serves as an additional feature to provide information about the condition of the engine with sound, especially when the emergency switch is "ON". The solenoid valve and manifold solenoid valve are electronic devices used to regulate the flow of liquid into the bottle and operate the pneumatic cylinder to raise and lower the nozzle position.

Flowchart

As shown in the flowchart of Figure 3, the filling process using the machine begins with the user selecting the nozzle units to be used and activating them by turning on the ON/OFF switch on each nozzle unit. After that, the user selects the product variant by setting the filling set points to "Alarm 1" (Lower Limit) and "Alarm 2" (Upper Limit) on the MYPIN Weighing Indicator.

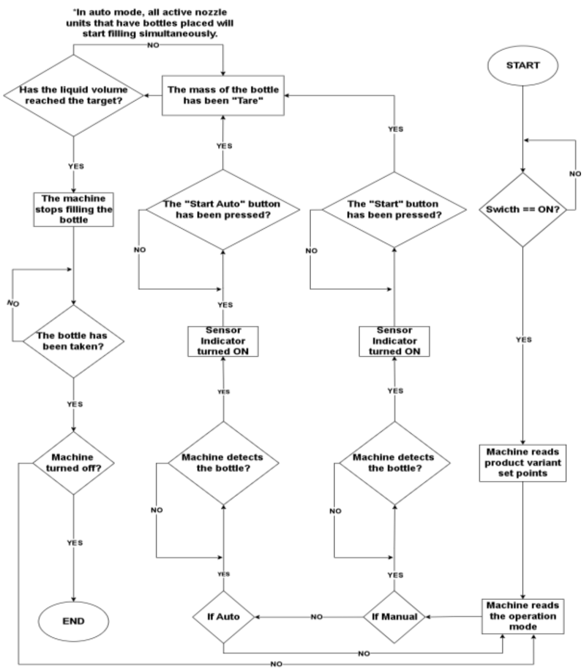

FIGURE 3. Automatic filling machine flow chart.

Next, the user selects the machine operation mode, i.e., "Manual" or "Automatic", which affects the way of filling. In "Manual" mode, the user manually clicks the "Start" button on each nozzle unit, while in "Auto" mode, the user simply clicks the "Auto Start" button to automatically fill each active nozzle unit. After selecting the operating mode, the user places bottles on each nozzle unit. The photoelectric sensor detects the placed bottle, ensuring that the filling process only runs if the bottle has been placed.

The user can start the filling process by pressing the "Start" or "Auto Start" button. The process begins by resetting the bottle mass reading obtained from the loadcell by MYPIN, ensuring accuracy of the reading during the filling process.

Next, the pneumatic cylinder moves the nozzle into the bottle, opens the solenoid valve, and activates the pump to start filling the liquid product. When the product mass reading reaches "Alarm 1", the motor rotation speed on the pump is slowed down.

When it reaches "Alarm 2", the pump is turned off, the solenoid valve is closed, and the pneumatic cylinder lifts the nozzle from the bottle, completing the filling process. After completion, the bottle filled with the product can be taken away, and the production process can continue. After the production process is completed, the machine can be shut down.

B. Hardware Specification

Table 3 presents the components installed on the machine.

TABLE 3. Hardware specification.

Component	Specification
Box Panel	710 mm × 300 mm × 400 mm
Push Buttons with Indicator Lamp (Red, Green, Yellow)	24V DC Schneider
Switches and Emergency Switch	24V DC Schneider
Indicator Lamp (Green)	24V DC Schneider
Tower Lamp (Red, Yellow, Green) with Buzzer	SMC NPT5A-3T-D-J DC
Weighing Indicator	MYPIN Weighing Indicator LH86E-IRR2D
Solenoid Valve	Brando 2S160-15
Manifold Solenoid Valve	Manifold solenoid valve SMC SY3120-5LZ-C4
Pneumatic Cylinder	Pneumatic Cylinder SMC CDQ2B32-50DCMZ
Photoelectric sensor	Photoelectric sensor E3F DS30P1
Loadcell	Loadcell CZL-882
Power Supply	Siemens 6EP1333-3BA00
PLC CPU	SIMATIC S7-300, PLC CPU 315-2DP 6ES7315-2AH14-0AB0
I/O Module	Siemens 6ES7321-1BL00-0AA0/6ES7322-1BL00-0AA0
MCB	1 phase
Relay	MY2N 24 VDC OMRON
Compute Relay	TRS 24 VDC 1CO Weidmuller
Pump	EBARA CDX 90/10 Pump
Pump Inverter	FUJI FRN0006C2S-7A 0,75kw
Micro Memory Card	128 kbyte, Siemens 6ES7953-8LG31-0AA0

C. Panel Mapping

Figure 4 shows a mapping of the operation panel on the Automatic Filling Machine. Each nozzle has a Start button, Stop button, Tare and TestPos button, ON/OFF Switch, Bottle Position Indicator, and MYPIN Weighing Indicator. are tower lamps colored red, yellow, green, and buzzer.

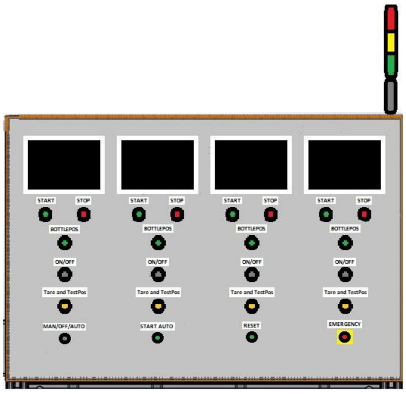

FIGURE 4. Automatic filling machine operation panel mapping.

Apart from that, there are several special components on the panel, namely the operating mode switch, Auto Start button, Reset Buzzer button, and Emergency Switch. On the top side of the panel, there are tower lamps colored red, yellow, green, and buzzer.

D. Electrical Wiring Design

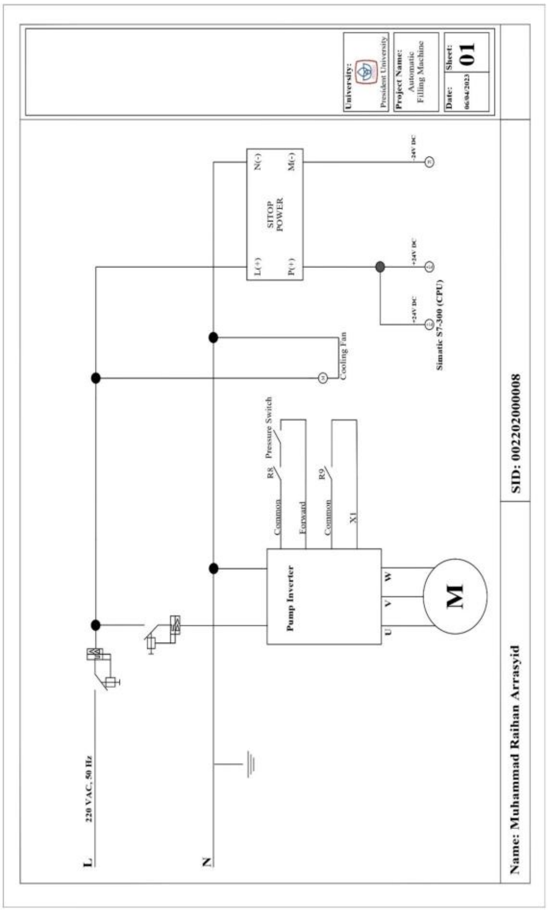

FIGURE 5. Automatic filling machine electrical wiring diagram.

As shown in Figure 5, the electrical system on this machine uses a 1-phase 220 VAC voltage to deliver electricity to the Socket Outlet, activate the cooling fan, and activate the Power Supply. The Power Supply is used to distribute 24 VDC electricity to various components on the machine, such as PLC Central Processing Unit (CPU), PLC Input Modules, PLC Output Modules, MYPIN, Photoelectric sensors, Buttons, Buzzers, Indicator Lights, Solenoid Valves, and Manifold Solenoid Valves.

IV. RESULT AND DISCUSSION

A. Testing Result

Operational qualification and software Testing

Operational Qualification (OQ) needs to be conducted on this filling machine to ensure that the machine can be operated properly before being used in the production process. Operational Qualification (OQ) consists of functional tests on the components installed on the machine. Based on the Operational Qualification results in Table 4, the machine can function properly, and the program can work properly with no bugs found that occur when the program is being run when the Operational Qualification is conducted.

TABLE 4. Operational qualification result.

No.	Stages	Acceptance Criteria	Actual Result
1.	Electrical Installation	There is no short circuit on the Panel.	There is no short circuit.
		When the MCB is activated, the power supply and PLC indicator lights are active.	The Power supply and PLC indicator lights are active.
2.	Tagging Optimization	The product filling set point can be set.	Able to set.
		The product filling duration can be set.	Able to set.
		All buttons on the panel can be operated.	All buttons can be operated.
		The operation mode can be set.	Operation mode can be set.
3.	Bulk Supply	The pump operates well and can supply bulk into bottles.	The pump can be operated
4.	Emergency Indicator	The emergency indicator functions properly	All emergency indicators can be operated.

Design Result

This automatic filling machine has been able to operate and can be used on the liquid production line for the production process of high-level disinfectant products, namely Metracide variant 1 liter. Figure 6 is the machine's front view and the panel's inside view.

This automatic filling machine is expected to improve the liquid production process to become more effective and efficient by reducing cycle time and increasing the yield and quantity of output.

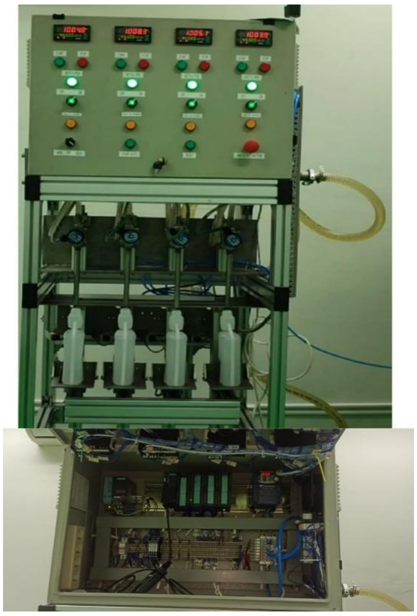

FIGURE 6. **Automatic filling machine front and inside panel view.**

B. Performance Analysis

Loadcell Readings Accuracy

As shown in Figure 7, The tests were conducted to determine the performance and accuracy of loadcell readings. The test was carried out by comparing the mass reading on the loadcell with a digital scale using a 1 kg weight and a 1-liter variant of the Metracide sample product and the second loadcell reading test uses a 1-liter variant of the Metracide product sample taken from the Quality Control (QC) lab with a mass of 1008.4 grams. Before starting the test, the digital scales and each loadcell on each nozzle were pre-tared with bottles that would later be filled with Metracide samples from QC so that the digital scales and machines only displayed the mass of the liquid bulk.

(a) (b)

FIGURE 7. **Loadcell reading test; (a) using 1 kg weight and (b) using Metracide 1-liter variant sample product.**

As shown in Table 5, the loadcell on each nozzle can read the mass of a 1kg and Metracide 1-liter variant sample product load accurately with a resolution of ± 0.1 grams.

TABLE 5. Loadcell reading test result.

Nozzle	Reading (gram)		Resolution (gram)
	Using 1 kh weight	Using Metracide 1 liter sample product	
1	1000.0	1008.4	± 0.1
2	1000.0	1008.4	±0.1
3	1000.0	1008.4	± 0.1
4	1000.0	1008.4	± 0.1

Yield Rate Calculation

The effectiveness of the production process is measured through the Yield Rate of each production batch. Based on the production data of Metracide variant 1 liter using the new machine in Table 6, in batch 1, the machine can produce output with a status of "Good" in as many as 488 bottles and "Not Good" in as many as 8 bottles. After rework, the total output obtained in this batch was 495 bottles and based on the calculation of the Yield rate value, this batch obtained a value of 98.58%.

Based on the production data of batch 2, the machine produced 489 bottles with "Good" status and seven bottles with "Not Good" status. Like the previous batch, after reworking the products with "Not Good" status, the total output obtained in this batch was 495 bottles, and based on the calculation of the Yield rate, the score obtained in this batch was 98%.

In batch 3, the machine produced 486 bottles with "Good" status and 10 bottles with "Not Good" status. After reworking the products with the "Not Good" status, the total output obtained in this batch was 495 bottles, and based on the amount of output obtained, the Yield rate score for this batch was 98%.

TABLE 6. New filling machine yield rate.

Date	September 18, 2023	September 19, 2023	September 20, 2023
Batch	1	2	3
Good pieces	488	489	486
Rework (Not Good)	8	7	10
Rework Output	7	5	9
Total Output	495	495	495
Yield Rate	98.58%	98.78%	98.18%

Cycle Time Calculation

The cycle time of each production batch is the measurement of the efficiency of the production process. Based on the data of 3 production batches in Table 7, the production process at the filling station using the new machine only takes 4 seconds to produce one bottle output.

TABLE 7. New filling machine cycle time.

Batch	1	2	3
Start	10:28 AM	10:30 AM	10:25 AM
Finish	11:01 AM	11:03 AM	10:58 AM
Production Time	33 minutes	33 minutes	33 minutes
Total Output	495	495	495
Cycle time per bottle (Second)	4	4	4

Time Loss

In the production process using the new filling machine, some outputs do not meet product specifications, so they are included in the "Not Good" status. The rework process on the "Not Good" output still uses the same method as in the production process using the old filling machine, which takes 3 seconds to rework one bottle. Because there are still outputs that do not meet product specifications in the production process using this new filling machine, there is still time loss. The time loss can be seen in Table 8 using the new filling machine.

TABLE 8. Time loss in the production process using the new filling machine.

Batch	Rework (Not Good Output)	Time Loss (Minute)
1	8	0.4
2	7	0.3
3	10	0.5

Natural Production Loss

The production process of the 1-liter variant of Metracide using a new automatic filling machine has reduced the amount of natural production loss in the production process. As shown in Table 9, using a new filling machine, the average natural production loss in the production process is five bottles.

TABLE 9. Natural production loss in the production process using the new filling machine.

Batch	Total Output	Production Maximum Target
1	495	500
2	495	500
3	495	500

C. Improvement Analysis Discussion

Yield Rate Comparison

Based on the data displayed in Table 10, it can be seen that the old machine produces a lot of output that is not in accordance with predetermined specifications, and this causes the yield rate score obtained to be much lower than the new machine, from 3 batches of production the highest score obtained only reaches 57.14%. The low-yield rate score indicates that the production process at the station is running ineffectively because the large number of outputs that do not meet the predetermined specifications results in a loss of time in the production process at the filling station because there is much product rework.

By using a new machine in the production process, the average yield rate score increased to 98.51% because the machine can produce output in accordance with the specifications set by the company. In addition to the increase in the yield rate score, the reduction of "Not Good" products in the production process causes the total actual output to increase from 490 bottles to 495 bottles per batch, and this also affects the reduction of time loss in each production batch by 96% and also reduces the natural production loss to 5 bottles in each production batch. By increasing the yield of output, which causes a reduction in time and natural production loss, it shows that the production process becomes more effective by using this automatic filling machine.

TABLE 10. Old and new filling machine yield rate comparison.

	Batch	*Good*	*Not Good*	*Output*	*Yield Rate*
Old Machine	1	280	210	490	57.14%
	2	247	243	490	50.40%
	3	237	253	490	48.36%
New Machine	1	488	8	495	98.58%
	2	489	7	495	98.78%
	3	486	10	495	98.18%
	Batch	*Natural Production Loss (Bottle)*		*Time Loss (Minute)*	
Old Machine	1	10		10.5	
	2	10		12.15	
	3	10		11.85	
New Machine	1	5		0.4	
	2	5		0.3	
	3	5		0.5	

Cycle Time Comparison

Based on the data shown in Table 11; to produce an output of 495 bottles, the new machine only takes an average time of 33 minutes. Whereas when using the old filling machine in the production process, to produce an output of 490 bottles takes an average time of 134 minutes. Reduced production time at the filling station by 75.49% faster than the old machine and increased output quantity, showing that the production process became more efficient.

E-ISSN: 2682-860X

TABLE 11. Old and new filling machine cycle time comparison.

Machine	Old			New		
Batch	1	2	3	1	2	3
Total Output	490	490	490	495	495	495
Production Time (Minute)	133	134	137	33	33	33
Cycle Time/bottle (Second)	17	17	22	4	4	4

V. CONCLUSION

This Automatic Filling Machine has succeeded in improving the yield of output compared to the old machine so that the production process becomes more effective. Based on In Process Control (IPC) Automatic Filling Machine data obtained from 3 batches of 1-liter variant Metracide production using the new machine, the average yield rate score obtained is 98.51%, where this score has successfully increased 46.55% greater than the average yield rate score of the production process using the old filling machine. With the increase in output yield in the production process, this machine also succeeded in reducing time loss by 96% and reducing natural production loss in each production batch from 10 bottles to 5 bottles so that the production process became more effective.

This Automatic Filling Machine succeeded in reducing the cycle time so that the production time at the filling station became much faster than using the old machine. Based on In Process Control (IPC) Automatic Filling Machine data obtained from 3 batches of 1-liter variant Metracide production using the new machine, the average time required for filling the product into bottles is 33 minutes for 495 bottles.

This Automatic Filling Machine also managed to increase the output quantity compared to the old machine. Before using the new filling machine, the average output obtained from each production batch only amounted to 490 bottles. With the new filling machine, the output increased to 495 bottles per batch. Increasing the quantity of output with a faster production time shows that this Automatic Filling Machine has made the production process more efficient.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Global Medipro Investama LLC for the opportunity to conduct and work on research there. We are very grateful for the support that has been given in carrying out this research.

FUNDING STATEMENT

There is no financial support from any agencies funding this research work.

AUTHOR CONTRIBUTIONS

Muhammad Raihan Arrasyid: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation.

Iksan Bukhori: Project Administration, Supervision, Writing – Review & Editing

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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