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Implementation of Automatic Temperature Control Technology to Improve Powder Coating Oven Efficiency at PT. Denkindo Central Elektrik

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ABSTRACT

PT. Denkindo Central Elektrik applies powder coating technology in its electrical panel production, where stable oven heating is essential. Manual regulation often leads to LPG freezing and unstable combustion, increasing fuel consumption. To address this, an automatic temperature control system was developed using a DS18B20 sensor, ESP32 microcontroller, ON/OFF relay, and water heating support. Calibration against a water thermometer showed an average error of 1.96%, ensuring accuracy. The system was tested over 45-minute production cycles with 3-minute intervals, and LPG consumption was measured by cylinder weight. Results showed LPG temperature dropped to 23.2 °C under manual operation but was maintained at 37–40 °C with control, preventing freezing risk. While oven performance to reach 180 °C was similar (24 minutes), LPG consumption decreased from 3.65 to 1.85 kg per cycle, saving 1.8 kg (Rp36,000). With an investment of Rp1,500,000, the break-even point is reached after 42 cycles. These findings indicate improved safety, efficiency, and economic benefit, though validation was limited to two cycles.

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INTRODUCTION

PT. Denkindo Central Elektrik is a micro-industry engaged in the manufacturing of electrical panels. The company's upstream business includes the production of electrical panels, the design of mechanical and electrical systems, and the supply of electrical components. On the downstream side, PT. Denkindo also provides installation and commissioning of electrical systems, maintenance and repair of electrical panels, as well as mechanical and electrical system assessment services for various industrial sectors. In its production process, the company applies powder coating technology to coat product surfaces with powder-based paint. One of the crucial stages in this process is heating in the powder coating oven to ensure an even and durable coating result. However, several key problems arise in the operation of this oven, namely temperature instability and the freezing of LPG used as the heating fuel. Temperature fluctuations often occur because oven temperature control is still carried out manually. Therefore, the application of automation in manufacturing has been increasingly adopted through technologies such as Arduino or PLC (Programmable Logic Controller). An automatic control system operates independently (without human intervention), while a semi-automatic control system still requires some manual input (Purbodjati & Sulistiyo, 2021). Automatic control to solve oven temperature instability can be achieved through the addition of a PID (Proportional-Integral-Derivative) controller (Parmadi Putra, Arta Wijaya, & Budiastra, 2020). A PID controller can produce more stable temperatures and result in a more uniform and durable coating (Palomares Orihuela & Ricardo John, 2024).

Another problem is that the LPG used as oven fuel is prone to freezing when pressure drops drastically, especially under cold environmental conditions. If freezing occurs, LPG vapor pressure decreases significantly, making the fuel flow to the oven unstable and disrupting combustion. This condition also increases LPG consumption due to inefficient energy use. From a safety perspective, LPG has an operational temperature standard that should be kept below 50 °C. Too low a temperature (<20–25 °C) increases the risk of freezing, while too high a temperature (>50 °C) increases excessive pressure and may cause leakage hazards. Therefore, maintaining LPG temperature within the optimal range (30–40 °C) is essential not only for reducing fuel consumption but also for ensuring workplace safety and maintaining production stability (Ceviz, Kaleli, & Güner, 2015).

To overcome these problems, it is necessary to apply an innovative automatic LPG temperature control system. Such a system works by detecting anomalies in LPG and activating an auxiliary heater to prevent freezing (Boniface, Nasir, & Hassan, 2020). One auxiliary heater option is the use of a water heater, which helps maintain gas temperature stability and improves combustion efficiency (Florin Grofu & Constantin Cercel, 2019). An important part of this system is accurate temperature sensing and monitoring. The application of Internet of Things (IoT) technology in temperature control systems has been proven to improve the accuracy of real-time oven temperature monitoring (Winarno, Sembodo, & Affandi, 2022). Real-time monitoring can be carried out by combining IoT with temperature sensors. Several types of sensors are commonly used, such as type-K thermocouples, which can be read through digital displays and recorded by data loggers (Putrawan, Susila, & Suparta, 2024), as well as the LM35 sensor, which is widely used for its high accuracy (Khotib, Basri, Surya, & Iskawanto, 2021)In addition, the DS18B20 sensor provides higher accuracy and simpler usability as it directly produces digital output without the need for additional circuitry to convert analog signals.

Based on this background, the implementation of an IoT-based automatic LPG temperature control system with an auxiliary water heater can be a strategic solution for PT. Denkindo Central Elektrik. This technology not only maintains stable oven temperature in powder coating processes but also directly

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improves LPG efficiency, reducing fuel consumption and lowering operational costs.

METHOD

This study was carried out through three main stages: system design, implementation, and testing and evaluation, as illustrated in Fig. 1. The control system was designed using a DS18B20 digital temperature sensor, an ESP32 microcontroller, a relay module, and an auxiliary water heater to maintain LPG temperature stability. Before deployment, the DS18B20 sensor was calibrated against a reference water thermometer to ensure measurement accuracy, yielding an average error of less than 2%. The control algorithm applied was a relay-based ON/OFF mechanism with a setpoint of 50 °C and a hysteresis of ±10 °C.

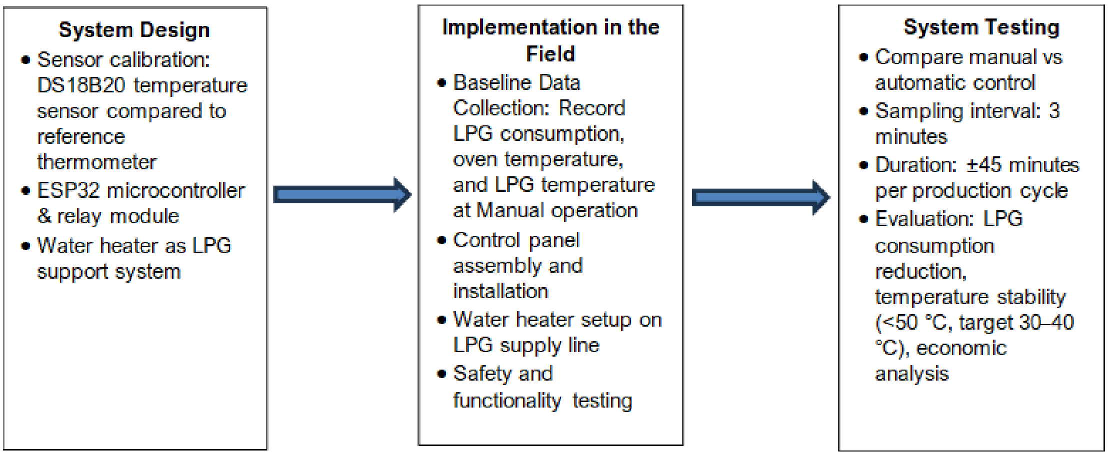

FIGURE 1. Flow of LPG Automatic Temperature Control Implementation

System implementation was conducted on the powder coating oven at PT. Denkindo Central Elektrik. The control panel and auxiliary water heater were installed outside the oven and along the LPG supply line, as shown in Fig. 2. Initial functional testing and electrical safety inspections were performed to verify that all equipment operated according to its intended design and that system parameters were within acceptable tolerance limits (Ratih Mar'atus Sholihah, Irwan Mahmudi, & Lutfiyana Andi Anshar, 2024). Baseline (pre-implementation) measurements under manual operation were recorded to establish comparative data on LPG consumption, LPG temperature, and oven heating time.

FIGURE 2. Layout of Control Panel Position in Powder Coating Oven Room

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Performance testing was conducted by comparing manual and automatic control conditions, each evaluated over several complete production cycles (±45 minutes per cycle). Water heating temperature data were recorded using a data logger with a logging interval of 3 minutes, while LPG consumption was measured using the cylinder weight difference before and after each test. System effectiveness was assessed based on LPG savings, LPG temperature stability relative to the safety threshold (<50 °C), and economic feasibility through cost savings and investment payback period calculations.

RESULTS AND DISCUSSION

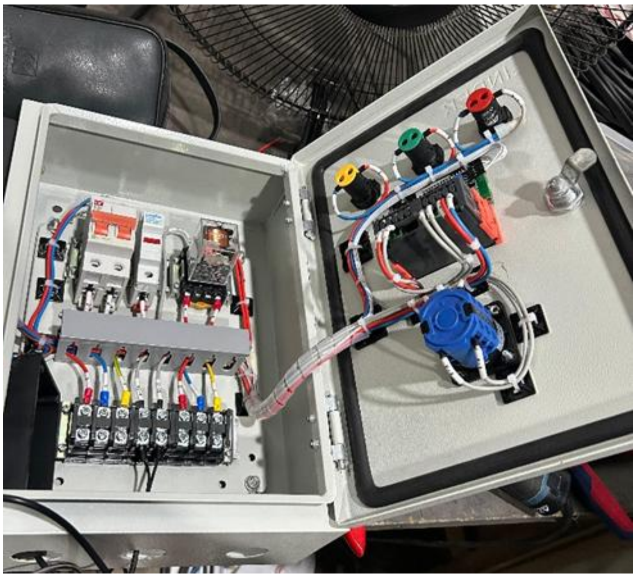

FIGURE 3. LPG Temperature Control Panel

The developed LPG temperature control panel is shown in Fig. 3. Before deployment, the DS18B20 digital temperature sensor was calibrated against a reference water thermometer. The calibration results, presented in Table 1, indicate an average error of 1.96%, with a maximum deviation of 4.00%. These values are sufficiently low for industrial applications, demonstrating the sensor's reliability in maintaining accurate LPG temperature measurements. The sensor was programmed to drive the ON/OFF relay logic for the auxiliary heater, activating the heater when the temperature dropped below 40 °C and deactivating it when the temperature reached 60 °C. With IoT integration, the temperature could be monitored in real time and remotely, thus enhancing system functionality.

TABLE 1. Comparison of Heating Water Temperature Readings by DS18B20 Sensor and Water Thermometer

No	Water Temperature (˚C)		error
	DS18B20 sensor	Water Thermometer	
1	44,81	45	0,42%
2	45	46	2,17%
3	44,31	45	1,53%
4	44,62	45	0,84%
5	44,56	45	0,98%
6	44,12	45	1,96%
7	45	45	0,00%

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No	Water Temperature (˚C)		error
	DS18B20 sensor	Water Thermometer	
8	44,56	46	3,13%
9	44,88	46	2,43%
10	44,62	46	3,00%
11	44,69	46	2,85%
12	44,88	46	2,43%
13	45,75	46	0,54%
14	45,06	46	2,04%
15	45,56	45	1,24%
16	45,31	45	0,69%
17	44	45	2,22%
18	43,94	45	2,36%
19	43,94	45	2,36%
20	44,19	45	1,80%
21	44,2	45	1,78%
22	44,22	45	1,73%
23	44,3	45	1,56%
24	44,2	45	1,78%
25	43,3	45	3,78%
26	44,16	45	1,87%
27	43,5	45	3,33%
28	43,2	45	4,00%
29	44	45	2,22%
30	44,2	45	1,78%

Manual testing (without auxiliary heating control) revealed that LPG temperature gradually decreased from 29 °C to 23.2 °C over 45 minutes. This final temperature approaches the critical threshold for LPG freezing (<25 °C), which poses a risk of fuel supply instability. In contrast, when heating control was enabled, LPG temperature was maintained within a stable range of 37–40 °C throughout the 45-minute cycle, fully aligned with the recommended safety range of 30–40 °C. Oven heating performance was also assessed: the target operating temperature of 180 °C was reached at minute 24 in both cases, indicating that heating control did not significantly delay oven warm-up. These results are summarized in Table 2, while the thermal response curves are illustrated in Fig. 4, where panel (a) shows LPG temperature decline without control and panel (b) shows oven temperature stabilization under both conditions.

TABLE 2. LPG and Oven Temperature Profiles with and Without Heating Control

No	Time (minute)	Temperature Without Control (°C)				Temperature With Control (°C)			
		Day 1		Day 2		Day 1		Day 2	
		At LPG	In Oven	At LPG	In Oven	At LPG	In Oven	At LPG	In Oven
1	3	29	62	24,7	87	35,9	57	40,3	68
2	6	27,9	107	23,5	130	38	98	38,1	98

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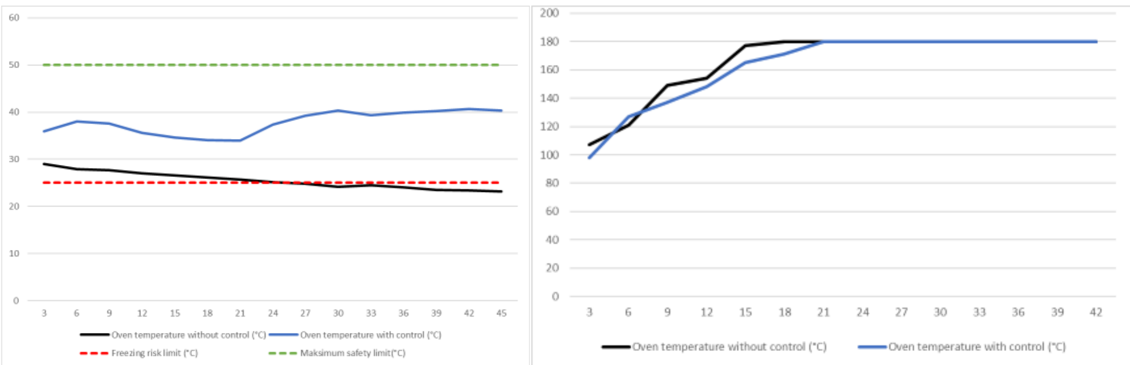
No	Time (minute)	Temperature Without Control (°C)				Temperature With Control (°C)			
		Day 1		Day 2		Day 1		Day 2	
		At LPG	In Oven	At LPG	In Oven	At LPG	In Oven	At LPG	In Oven
3	9	27,7	121	22,7	144	37,6	127	38,7	124
4	12	27	149	22,2	168	35,6	137	38,1	140
5	15	26,6	154	22	178	34,6	148	39,6	158
6	18	26,1	177	21	**180**	34,1	165	36,1	168
7	21	25,7	**180**	20,5	180	34	171	37,9	171
8	24	25,2	180	20,7	180	37,4	**180**	37,4	**180**
9	27	24,8	180	20,8	180	39,2	180	37,5	180
10	30	24,2	180	20,2	180	40,4	180	37,2	180
11	33	24,5	180	19,9	180	39,4	180	37,3	180
12	36	24,1	180	19,8	180	39,9	180	37,2	180
13	39	23,5	180	19,7	180	40,2	180	38,3	180
14	42	23,4	180	19,6	180	40,7	180	38,1	180
15	45	23,2	180	19,7	180	40,3	180	39,2	180



(A) (B)

FIGURE 4. Temperature Response: (a) LPG and (b) Oven

The effectiveness of the control system was further evaluated based on LPG consumption. As presented in Table 3, the weight difference before and after each 45-minute production cycle indicates a reduction of 1.8 kg of LPG when the heating control was applied. This corresponds to a cost saving of approximately IDR 36,000 per cycle, assuming a non-subsidized LPG price of IDR 20,000/kg. Considering the investment cost of IDR 1,500,000 for system implementation, the break-even point is achieved after approximately 42 production cycles.

TABLE 3. LPG Consumption With and Without Heating Control

Condition	LPG Weight (kg)		LPG Consumption (kg)
	Initial	Final	
without control	26,1	22,45	3,65
with heating control	23,45	21,6	1,85
Savings			1,8

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From a technical perspective, the automatic control system effectively maintained LPG temperature within the optimal range (37–40 °C), thereby preventing freezing risks and ensuring stable fuel supply. Although the time required to reach the oven setpoint temperature of 180 °C remained nearly identical between manual and controlled operation (24 minutes), the system provided distinct advantages in terms of fuel stability and energy efficiency. From an economic standpoint, the observed savings of IDR 36,000 per cycle demonstrate tangible reductions in operational costs. Over long-term use, the higher the production frequency, the greater the economic benefit realized by the company.

CONCLUSION

The implementation of an automatic LPG temperature control system based on the DS18B20 sensor, an ON/OFF relay, and a water heater in the powder coating oven at PT. Denkindo has been proven to maintain LPG temperature stability within the range of 37–40 °C, thereby mitigating the risk of fuel freezing. The system also contributes to a reduction in LPG consumption by 1.8 kg per production cycle, equivalent to approximately IDR 36,000 in cost savings, with an estimated investment payback period of ±42 production cycles. These findings indicate the potential for significant energy efficiency improvements and operational cost reduction.

Nevertheless, this study has several important limitations. Testing was conducted on only two production cycles of 45 minutes each, resulting in limited data for long-term validation. Environmental factors such as humidity and ambient temperature were not analyzed, and no statistical tests were performed to evaluate the significance of the results. Therefore, these outcomes should be regarded as preliminary but promising, rather than sufficient for broad industrial generalization.

Future work should focus on conducting replicated experiments with a larger sample size, applying comprehensive statistical analyses, and extending long-term testing to evaluate system reliability. Furthermore, opportunities exist for advancement through the integration of more sophisticated control algorithms, such as fuzzy logic or PID, to enhance control precision. From an industrial perspective, further studies should also investigate system scalability for larger-capacity ovens and assess its broader impact on productivity and occupational safety standards.

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