Journal of Airport Engineering Technology (JAET)
https://e-journal.poltekbangplg.ac.id/index.php/jaet

Volume: 6, No. 2. June, 2026: pp. 61-68
E-ISSN; P-ISSN: 2774-9622; 2775-4871
DOI: 10.52989/jaet.v6i2.270
Submitted: 2026-03-20; Revised: 2026-04-28; Accepted: 2026-05-29

SPEED TOOL INNOVATION FOR ROUTINE MAINTENANCE OF PERSONAL PROTECTIVE EQUIPMENT

M. Fadli[1], Thursina Andayani[2]
[1]Sangia Nibandera Airport, Sulawesi Tenggara, Indonesia
[2]Airport Rescue and Fire Fighting Study Programme, Politeknik Penerbangan Palembang, Indonesia
*Correspondence e-mail: mfadliak22@gmail.com

Abstract
Personal Protective Equipment (PPE) is critical for Airport Rescue and Fire Fighting (ARFF) personnel, yet its maintenance—particularly drying—remains manual and weather-dependent, creating risks of microbial growth and reduced protective effectiveness. This study developed the SPEED device (Effective, Efficient, and Powerful PPE Drying System) using a Research and Development (R&D) approach with the ADDIE model. Data were collected through observation, interviews, and expert validation at the ARFF Unit of Yogyakarta International Airport. SPEED integrates a heating element, exhaust fan, and UV-C lamp (344 W total) with automatic temperature and timer control. Expert validation by three ARFF practitioners and one academic validator yielded a score of 100% ("Very Feasible"). Performance testing confirmed that SPEED dries PPE within 15–60 minutes, up to 16 times faster than conventional sun-drying (180–240 minutes). This innovation improves PPE maintenance efficiency, ensures hygiene, and supports ARFF operational readiness.
Keywords: *ARFF, drying system, innovation, personal protective equipment, SPEED*

Introduction

The primary mission of Airport Rescue and Fire Fighting (ARFF) services is to protect passengers, aircraft, and airport facilities during accidents or incidents (Abdullah et al., 2024). These operations demand rapid and precise responses to ensure the safety of passengers, crew, and airport personnel. ARFF teams must adhere to strict international standards, particularly those outlined by the International Civil Aviation Organization (ICAO), which define the required equipment, response time, and operational procedures for managing aviation emergencies. Personal Protective Equipment (PPE) is an essential component for firefighting personnel, both during emergency operations and routine training. Among the most critical types of PPE is the firefighter suit, which is designed to protect the body from high temperatures, flames, steam, and hazardous substances. Despite its protective design, prolonged use of firefighter suits can cause several health issues, particularly skin-related conditions (Jaradat et al., 2020; Toole, 2025). Firefighter suits are made from multilayered, tightly sealed materials to resist heat and chemicals.

However, this design limits air circulation and traps sweat produced during strenuous activity. As a result, it creates a warm, moist environment that is ideal for the growth of microorganisms such as bacteria and fungi. If a firefighter suit is not properly dried after use, it may increase the risk of skin infections. (Horváth & Pántya, 2024; Krzemińska & Szewczyńska, 2022). Prolonged exposure to damp PPE has been linked to heat rash, irritation, and inflammation, while pressure and friction from the suit can worsen skin microtrauma (Fourie et al., 2022; Lu & Jiang, 2023). Inadequate ventilation and delayed drying of workwear are major causes of skin infections among field workers (Watson et al., 2022). Although technological advances have improved PPE design, the maintenance process, particularly drying efficiency, remains a weak point.

At the ARFF Unit of Yogyakarta International Airport, the current drying method still relies on sun exposure, which is time-consuming and weather-dependent. This limitation can hinder operational readiness and pose health risks to personnel due to prolonged moisture retention. In response to this research gap, this study introduces SPEED (Effective, Efficient, and Powerful PPE Drying System)—an innovative PPE drying system designed to accelerate drying automatically (Lou et al., 2022). The device integrates a heating element, exhaust fan, and UV-C light to eliminate moisture and destroy harmful microorganisms (Rasouli et al., 2024). This automated system aims to make PPE maintenance faster, more efficient, and more hygienic, thereby enhancing the operational readiness and health protection of ARFF personnel.

Several studies have explored automated drying technologies as alternatives to conventional sun-drying. (Purwadi & Kusbandono, 2016) demonstrated that adding an exhaust fan significantly reduces drying time and accelerates evaporation in cabinet-type garment dryers, thereby establishing the mechanical principle underlying forced-air drying systems. (Kadriadi et al., 2023) developed a hot-air garment dryer using a heating element and reported effective drying performance, confirming the feasibility of in compact heated enclosures for workwear maintenance. (Syamsuri et al., 2023) further investigated the effect of variations in fluid flow rate on drying capacity in cabinet dryers, showing that airflow optimization is critical for achieving uniform drying outcomes. (Rustiawan et al., 2022) developed an automatic garment dryer using a ceramic heating element integrated with a Rex C-100 temperature sensor, demonstrating that thermostat-controlled heating significantly improves drying consistency and prevents overheating. At the component level, (Dwi et al., 2019) prototyped an IoT-based automatic clothesline and dryer system, and (Putri, 2019) and (Madhuri et al., 2025) independently developed Arduino-based automatic dryers, confirming that automated control systems are technically feasible for garment drying applications.

Despite these advances, none of the existing systems were designed specifically for ARFF personal protective equipment, nor do they integrate UV-C sterilization, a critical dimension for PPE hygiene given the documented risks of microbial contamination on damp protective garments (Menezes, 2020; Yuliani & Amalia, 2019). Furthermore, no prior study has evaluated automated drying solutions within the regulatory framework of aviation rescue and firefighting operations as defined by PR 30 (2022) and KP 04 (2013).

Based on this review, a clear gap exists. While automated garment drying technologies have been developed and validated in general textile and workwear contexts, no device has been specifically engineered for ARFF PPE maintenance in aviation settings. Existing dryers remove moisture but do not simultaneously deliver UV-C sterilization to neutralize pathogens, which is essential given the high risk of microbial exposure faced by ARFF personnel (Musbandi, 2024; Pratama, 2021). Additionally, current ARFF units, including YIA Kulon Progo, operate without a standardized drying protocol or dedicated drying equipment, a gap that is inconsistent with the preventive maintenance obligations stipulated in PR 30 (2022) and KP 04 (2013). This study therefore addresses the intersection of three unmet needs: drying speed, microbial safety, and ARFF operational compliance.

Therefore, the objective of this study is to analyze and evaluate the effectiveness of PPE maintenance at the ARFF Unit of Yogyakarta International Airport using the SPEED device. The findings are expected to contribute to the development of practical innovations in firefighting equipment maintenance, particularly in the aviation safety sector. This research also supports preventive maintenance efforts to ensure that all PPE remains in optimal condition for emergency response operations.

Methods

This study applied a Research and Development (R&D) approach using the ADDIE model which steps from Analysis, Design, Development, Implementation, and Evaluation (Rahayu, 2025) to develop the SPEED device (Effective, Efficient, and Powerful PPE Drying System). The R&D method was chosen to systematically design, validate, and test an innovative drying system for ARFF protective equipment, informed by field needs and expert assessments.

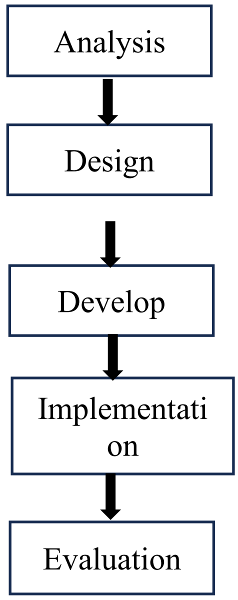

Figure 1. Development Stage

The research was conducted at the Airport Rescue and Fire Fighting (ARFF) Unit of Yogyakarta International Airport (YIA) from September 2024 to January 2025. The participants included one materials expert from the Aviation Polytechnic of Palembang and three ARFF operational officers serving as practitioners. The experts were responsible for validating the design, functionality, and effectiveness of the developed system, while practitioners provided feedback on its usability in real operational contexts.

Data collection techniques consisted of observation, interviews, and questionnaires. Observations were conducted to examine the current condition and maintenance process of ARFF protective equipment. At the same time, interviews were used to gather expert and practitioner insights regarding equipment handling and drying requirements. Questionnaires were distributed to obtain quantitative assessments of the product's feasibility, including usability, efficiency, and practicality. The collected data were analysed using descriptive quantitative methods. Expert evaluations were converted to percentages using a feasibility formula, and the results were interpreted across five rating categories, ranging from "Highly Feasible" (81–100%) to "Not Feasible" (0–20%). This validation process was intended to determine the overall feasibility and effectiveness of the SPEED device before its implementation in ARFF operations.

Table 1. Feasibility Percentage Categories

Criteria	Categori
84,01% – 100,00%	Very Feasible
68,01% – 84,00%	Feasible
52,01% – 68,00%	Sufficient
36,01% – 52,00%	Less Feasible
20,00% – 36,00%	Not Good

The feasibility percentage was calculated using the following formula:
Validation Value (%) = (Total scores obtained / Ideal maximum score) × 100%

Data reliability was ensured through expert triangulation. Performance testing compared drying outcomes between the SPEED device and conventional sun-drying across standardized time intervals (15, 30, 45, and 60 minutes for SPEED; 15, 30, 45, 60, 120, 180, and 240 minutes for sun-drying), using identical PPE items under controlled conditions.

Results and Discussions

Analysis Stage

Observation and interview findings at YIA Kulon Progo revealed critical deficiencies in the existing PPE maintenance system. Key findings are presented in Table 2.

Table 2. Summary of Observation Findings at ARFF Unit YIA Kulon Progo

No.	Observed Aspect	Finding
1	PPE Cleaning Procedure	Performed manually after each use; no standardized SOP for frequency or method.
2	PPE Storage	Stored separately but without temperature or humidity control.
3	Inspection & Maintenance	Routine checks conducted without written records, making it difficult to track conditions.
4	PPE Drying Facility	No dedicated drying equipment; personnel relied entirely on sun-drying, which is weather-dependent and time-consuming.
5	PPE Quality	Several items showed signs of wear (cracks, fading), indicating the need for more structured maintenance.

Interview data from three ARFF officers corroborated the observation findings. The ARFF Maintenance Chief confirmed that no dedicated drying equipment exists at the unit and that operations rely entirely on sun-drying. The Training Chief similarly noted the absence of any mechanical drying facility for heat-resistant garments. The Operations Chief validated the need for such a device and specifically recommended that future development include microbial testing on PPE before and after drying to strengthen hygiene assurance. These findings collectively establish a clear need for an automated PPE drying solution. Based on the analysis findings, SPEED was designed as an enclosed drying cabinet. The design was finalized using 3D modeling software, which enabled verification of dimensional accuracy and component placement prior to fabrication. The cabinet structure uses 2×2 cm galvanized hollow steel framing, with inner and outer panels of 4 mm plywood lined with aluminum foil to reflect and retain heat.

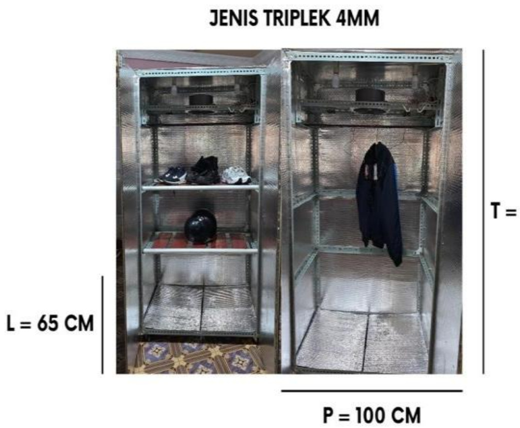

Figure 2. Final Design

Three core functional components were integrated: (1) a heating element (tubular stainless steel, stable up to extreme temperatures) to raise cabinet temperature to 30–60°C; (2) a 10-inch exhaust fan to ensure airflow and expel humid air; and (3) UV-C LED lamps (254 nm wavelength) to provide surface sterilization against bacteria, fungi, and viruses. Control systems include a Rex C-100 thermostat for automatic temperature regulation and an Omron H3CR-A8 digital timer for adjustable drying cycles (0–60 minutes). Total power consumption was calculated at 344 Watts, as detailed in Table 3.

Table 3. Power Calculation of SPEED Device Components

No.	Component	Qty	Power (Watt)
1	Exhaust Fan	1	30
2	Heating Element	2	300
3	UV-C LED Lamp	2	14
Total			**344 Watt**

Development Stage

The functional prototype was fabricated based on the approved design. During electrical circuit integration, two technical challenges were encountered: (1) the timer circuit did not initially function as intended, causing the thermostat and UV-C lamp to remain on continuously; and (2) the thermostat did not automatically limit temperature to the desired range. These issues were resolved through iterative consultation and circuit revision, guided by the academic validator. The revised circuit successfully achieved automatic temperature and time control as specified.

Expert validation was subsequently conducted to assess whether the prototype met the required technical and operational standards before field implementation. Four validators evaluated the device across dimensions of technical feasibility, effectiveness, energy efficiency, and operational suitability. Results are presented in Table 4. Expert validation from ARFF chiefs and an academic confirmed that the design met technical, operational, and academic standards, with all aspects rated "Highly Feasible" at 100%.

Table 4. Expert Validation Results for the SPEED Device

No.	Validator	Role	Result
1	Sukamto	ARFF Maintenance Chief, YIA	100% – Very Feasible
2	Moh Abdul Basyar	ARFF Training Chief, YIA	100% – Very Feasible
3	Aris Hervinsa Yulianto	ARFF Operation Chief, YIA	100% – Very Feasible
4	Dr. Anton Abdullah, S.T., M.M.	Academic Expert, Poltekbang Palembang	100% – Very Feasible

SPEED device was designed with an exhaust fan, heating elements, and UV-C lamps, requiring 344 Watts of power. Prototype development included 3D modeling, electrical schematics, and functional testing, addressing challenges in thermostat and timer integration.

Implementation Stage

Limited field trials were conducted to evaluate SPEED performance under realistic operational conditions. Multiple drying sessions were tested using heat-resistant uniforms, gloves, helmets, and boots. Key findings from the implementation phase are shown in Figure 2.

Figure 3. The Testing

Limited field trials were conducted under realistic operational conditions. At 15 minutes, SPEED successfully and uniformly dried heat-resistant garments and accessories (gloves, helmets, boots) that were damp from sweat or light surface moisture. At 30 and 45 minutes, drying was achieved, but the distribution was not fully uniform when garments were placed too closely together, restricting airflow. In three repeated 60-minute trials, with the load reduced to two garment pairs and items hung on hangers with adequate spacing, perfect and uniform drying was consistently achieved. These results confirm that load management and placement are critical parameters for optimal performance.

Evaluation Stage

A systematic comparison was conducted between SPEED and conventional sun-drying using identical PPE items across multiple time intervals. Summary results are presented in Table 5.

Table 5. Comparative Drying Performance: SPEED Device vs. Sun-Drying

Aspect	Sun-Drying	SPEED Device
Drying Time	180–240 min for partial drying	15–60 min for complete drying

Drying Quality	Non-uniform; inner layers remain damp	Uniform; outer and inner layers fully dried
Consistency	Weather-dependent; unreliable	Consistent when load and placement are optimized
Energy Cost	None (sunlight)	344 watts; faster and more efficient per cycle

A systematic comparison between SPEED and conventional sun-drying was conducted across multiple time intervals. Sun-drying failed to produce dry results in any trial up to 120 minutes. At 180 minutes, only the upper portions dried; at 240 minutes, only the surfaces directly exposed to sunlight dried, while the inner layers remained damp. In contrast, SPEED achieved complete drying within 15 minutes for lightly damp items and within 60 minutes for thoroughly wet garments—an improvement in time efficiency of up to 16-fold. These findings are consistent with prior studies on controlled drying systems, which show that forced convection combined with heating elements significantly accelerates moisture evaporation compared to passive solar exposure (Purwadi & Kusbandono, 2016; Syamsuri et al., 2023).

The inclusion of UV-C irradiation further differentiates SPEED by providing simultaneous microbial inactivation and addressing both the moisture and hygiene dimensions of PPE maintenance, a combination not achieved by sun-drying (Bartolomeu et al., 2022). A key limitation identified is that long-term effects of repeated heat exposure on PPE material integrity remain untested; material fatigue testing over multiple drying cycles is necessary before full-scale deployment. The drying efficiency demonstrated by SPEED, 15 minutes for lightly damp items and 60 minutes for thoroughly wet garments, is consistent with and extends findings from prior studies on forced-air heated cabinet dryers. (Zhou et al., 2025) showed that fan-assisted drying reduces drying time significantly compared to passive convection, a principle directly reflected in SPEED's exhaust fan integration. (Jiang et al., 2025) reported effective hot-air drying with a single heating element; SPEED employs dual heating elements (300 W total) combined with forced exhaust, which explains its superior throughput. (Tambunan, 2024) similarly confirmed that thermostat-controlled heating via Rex C-100 enables consistent and safe drying cycles — a finding replicated in SPEED's design. However, SPEED advances beyond these studies by incorporating UV-C irradiation (254 nm, 14 W) as a simultaneous sterilization layer, a feature absent in all comparable dryer prototypes reviewed.

The integration of UV-C light at 254 nm wavelength addresses a critical hygiene gap in existing drying solutions. The World Health Organization confirms that UV-C radiation at this wavelength is effective for surface disinfection against a broad spectrum of pathogens. This is particularly relevant to ARFF PPE, which is routinely exposed to environments with a high risk of microbial contamination. (Menezes, 2020) demonstrated fungal contamination (Aspergillus sp.) on clothing stored under suboptimal drying conditions, reinforcing the necessity of sterilization beyond mere moisture removal. The SPEED device therefore addresses not only the physical state of PPE (dryness) but also its microbiological safety — a dual function not achieved by any existing dryer prototype in the reviewed literature (Rasouli et al., 2024). However, the current study did not include laboratory-based microbial efficacy testing; this remains an important limitation and a priority for future validation work, as recommended by the ARFF Operation Chief during the implementation phase.

From a regulatory perspective, the SPEED device directly supports the preventive maintenance obligations mandated under PR 30-year 2022 and KP 04-year 2013, both of which require that ARFF operational equipment, including PPE, be maintained in a ready-to-use condition through documented periodic maintenance procedures. The current practice of sun-drying at YIA Kulon Progo, as confirmed by observation and interview, does not meet these standards: it lacks documentation, is weather-dependent, and leaves inner layers of PPE damp even after 240 minutes. The 15–60-minute drying cycle of

SPEED provides a predictable, controllable, and documentable maintenance workflow that aligns with operational shift patterns in ARFF units.

Several limitations of this study must be acknowledged. First, the sample size for field trials was limited to a single ARFF unit at a single airport, which constrains the generalizability of the findings. Second, no microbial testing was conducted to quantify the sterilization effectiveness of the UV-C component; this gap means the hygiene claims remain partially inferential. Third, the effect of repeated heat exposure (344 W, 30–60°C) on the structural integrity of PPE materials — particularly heat-resistant fabrics such as Nomex and Kevlar was not tested; as noted by (Kusuma et al., 2025), polymer-based protective materials can degrade under sustained thermal exposure. Fourth, the current prototype's capacity (two garment pairs per cycle) may be insufficient to meet full-scale ARFF operational demand. Future research should address these gaps through multi-site validation, laboratory microbial assays, material fatigue testing after repeated drying cycles, and prototype scaling.

Conclusion

The SPEED device was successfully developed and validated as an effective solution for preventive maintenance of PPE in ARFF operations. The device demonstrated a drying time of 15–60 minutes—up to 16 times faster than conventional sun-drying (180–240 minutes)—with superior uniformity, including complete drying of inner layers. Expert validation by three ARFF practitioners and one academic validator yielded a 100% feasibility score across all assessed dimensions. The integration of UV-C sterilization further supports PPE hygiene by reducing the risk of microbial contamination. These outcomes establish SPEED as a practical, applicable innovation that enhances operational readiness and occupational safety for ARFF personnel. Future development should address prototype scaling, material durability testing under repeated heat exposure, and laboratory-based microbial efficacy testing to support full-scale deployment.

References

Abdullah, A., Komalasari, Y., Nugraha, W., Hermala, Z., Amalia, D., El Firdaus, M. B., Rahmawaty, I. N., & Fadli, M. (2024). Inovasi PRO GALO untuk meningkatkan kompetensi dan pembelajaran pemeliharaan pakaian pelindung. *Jurnal Konseling dan Pendidikan*, *12*(4), 394–407.

Bartolomeu, M., Braz, M., Costa, P., Duarte, J., Pereira, C., & Almeida, A. (2022). Evaluation of UV-C radiation efficiency in the decontamination of inanimate surfaces and personal protective equipment contaminated with phage ϕ6. *Microorganisms*, *10*(3), 593.

Dwi, A., Rofiah, N., & Mumtahana, H. (2019). Perancangan prototype monitoring alat penjemur dan pengering pakaian otomatis dengan mikrokontroler berbasis thingspeak. *Journal of Computer and Information Technology*, *3*(1), 13–17.

Fourie, A., Muvhali, M., Carman, H., & Singh, T. (2022). Occupational skin disease associated with personal protective equipment: a case series. *Current Allergy & Clinical Immunology*, *35*(4), 223–231.

Horváth, L., & Pántya, P. (2024). New methods of maintenance and cleaning of firefighter's protective clothing by dry cleaning. *Hadmérnök*, *19*(3), 85–95.

Jaradat, Z. W., Ababneh, Q. O., Sha'aban, S. T., Alkofahi, A. A., Assaleh, D., & Al Shara, A. (2020). Methicillin resistant Staphylococcus aureus and public fomites: a review. *Pathogens and Global Health*, *114*(8), 426–450.

Jiang, D.-L., Shirkole, S. S., Ju, H.-Y., Niu, X.-X., Xie, Y.-K., Li, X.-Y., Lin, Z.-F., Zheng, Z.-A., & Xiao, H.-W. (2025). An improved infrared combined hot air dryer design and effective drying strategy analysis for sweet potato. *Lwt*, *215*, 117204.

Kadriadi, K., Wirakusuma, K. W., Pratama, A. B., Ariksa, J., & Yandi, W. (2023). Rancang bangun alat pengering baju menggunakan udara panas. *Machine: Jurnal Teknik Mesin*, *9*(1), 18–22.

Krzemińska, S. M., & Szewczyńska, M. (2022). Hazard of chemical substances contamination of protective clothing for firefighters–a survey on use and maintenance. *International Journal of Occupational Medicine and Environmental Health*, *35*(2), 235.

Kusuma, H. W., Lintang, S. S., Rohyani, T. A., Puspita, K. G., Muhlisa, L., & Khamid, M. N. (2025). The importance of Basic PPE usage in reducing the risk of occupational diseases and workplace accidents at PT Standard Toyo Polymer (STATOMER): pentingnya penggunaan APD dasar untuk meminimalisasi bahaya risiko penyakit dan kecelakaan kerja pada karyawan PT Standard Toyo Polymer (STATOMER).

Lou, L., Zhou, Y., Yan, Y., Hong, Y., & Fan, J. (2022). Wearable cooling and dehumidifying system for personal protective equipment (PPE). *Energy and Buildings*, *276*, 112510.

Lu, J., & Jiang, G. (2023). Guarding skin under PPE: Mechanistic insights and technological innovations. *Skin Research and Technology*, *29*(11), e13520.

Madhuri, A. V., Abduh, H., & Suppa, R. (2025). Prototype sistem penjemuran pakaian otomatis berbasis Arduino Uno. *Jurnal Informatika Dan Teknik Elektro Terapan*, *13*(1).

Menezes, H. (2020). Identifikasi jamur Aspergillus Sp pada pakaian bekas yang dijual di pasar pon jombang. *STIKes Insan Cendekia Medika Jombang.*

Musbandi, F. (2024). Hubungan pengetahuan tentang penggunaan Alat Pelindung Diri (APD) dengan kejadian ISPA pada petani sawit Di Desa Lubuk Batu. *(Skripsi) Thesis, Stikes Yarsi Pontianak*.

Pratama, M. A. (2021). Scooping review: Efektivitas penggunaan alat pelindung diri dengan kejadian dermatitis kontak pada pekerja pabrik. *Jurnal Riset Kedokteran*, *1*(1), 26–31.

Purwadi, P. K., & Kusbandono, W. (2016). Pengaruh kipas terhadap waktu dan laju pengeringan mesin pengering pakaian. *Teknoin*, *22*(7).

Putri, M. I. (2019). Rancang Bangun Alat Pengering Pakaian Otomatis Berbasis Arduino. *Jurnal Perencanaan, Sains, Teknologi, Dan Komputer*, *2*(2), 181–188.

Rahayu, A. (2025). Metode Penelitian dan Pengembangan (R&D): Pengertian, Jenis dan Tahapan. *DIAJAR: Jurnal Pendidikan Dan Pembelajaran*, *4*(3), 459–470. https://doi.org/10.54259/DIAJAR.V4I3.5092

Rasouli, S., Alipouri, Y., & Chamanzad, S. (2024). Smart Personal Protective Equipment (PPE) for construction safety: A literature review. *Safety Science*, *170*, 106368.

Rustiawan, I., Indra, I. B. P., & Ardana, I. (2022). Rancang bangun alat pengering pakaian bertenaga listrik dengan kapasitas 10 kg. Politeknik Negeri Bali.

Syamsuri, S., Lillahulhaq, Z., & Akhfaruhal, A. (2023). Pengaruh variasi laju aliran fluida terhadap kapasitas pengeringan pakaian (Tipe Pengering Lemari). *Turbo: Jurnal Program Studi Teknik Mesin*, *12*(1).

Tambunan, J. P. (2024). Rancang bangun sistem kontrol otomatis ruang pengering pakaian pada rumah tinggal berbasis Arduino dan kamera Wi-Fi.

Toole, A. M. (2025). Analysis of Burn Pattern Variations Caused by Synthetic Clothing on Pigs. *University of Idaho.*

Watson, C., Nawaz, N., Wardiningsih, W., & Troynikov, O. (2022). Materials used in industrial workwear for hot workplace environments: Thermal and moisture management attributes. *Journal of Industrial Textiles*, *52*, 15280837221141716.

Yuliani, I., & Amalia, R. (2019). Faktor-faktor yang berhubungan dengan perilaku pekerja dalam penggunaan Alat Pelindung Diri (APD). *Jurnal Ilmu Kesehatan Masyarakat*, *8*(01), 14–19.

Zhou, B., Han, X., Zhou, M., Li, Z., & Yang, B. (2025). Optimizing indoor air movement for comfort and health: a study of ceiling-based convective heating with reversed fan operation. *Building and Environment*, 113409.