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Fuel distribution controller for ARFF trainer with BACAK BAE: enhancing practical learning in aircraft firefighting operations

Anton Abdullah[1*)], Yeti Komalasari[1], I Gusti Ayu Mas Oka[1], Muhammad Kristiawan[2], Direstu Amalia[1]
[1] Politeknik Penerbangan Palembang, Indonesia
[2] Universitas Bengkulu, Indonesia

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ABSTRACT

ARFF services are vital for aviation safety, but traditional trainers struggle with fuel efficiency and environmental regulations. This study aims to develop a Fuel Distribution Controller for ARFF trainers to enhance fuel efficiency and compliance. The goal is to improve training while reducing operational costs. Borg and Gall's Research and Development (R&D) model is the foundational framework in this study. This R&D model typically comprises ten essential steps, but for this research, these steps are streamlined into three central stages: preliminary study, research development, and Validation. These stages collectively guide a methodical and structured research process, commencing with comprehensive preliminary investigations, progressing to developing a research solution, and concluding with a validation phase to ascertain the innovation's effectiveness. Professional insights from Politeknik Penerbangan Palembang inform the development of the Fuel Distribution Controller for the ARFF Trainer, aiming to improve practical aircraft firefighting training. This innovation enhances fuel efficiency, reduces environmental impact, and minimizes operational costs. The revamped system simplifies operations and provides a cost-effective, user-friendly learning experience. This achievement, verified by experts and users, holds significant promise for aircraft firefighting training and education.

Corresponding Author:

Anton Abdullah,
Politeknik Penerbangan Palembang
Email: anton@poltekbangplg.ac.id

Introduction

The primary purpose of ARFF (Airport Rescue and Fire Fighting) services is to save lives and prevent further damage to aircraft and airport facilities in the event of aircraft accidents or incidents at or around the airport(ICAO Doc. 9137 Part 1, 2014). ARFF is an integral part of aviation safety services every airport provides and must adhere to international standards set by the International Civil Aviation Organization (ICAO). ARFF services encompass providing protection against fire hazards, explosions, and other environmental dangers. These services also aim to create conditions that can sustain the lives of passengers and aircraft crew while providing escape routes and initiating rescue efforts for those who require immediate assistance. To achieve this goal, ARFF services involve trained teams equipped with firefighting and rescue equipment. ARFF teams must be ready to act swiftly in emergencies and continuously train and develop their skills to ensure they are prepared to face any scenario. To maintain safety standards and meet regulatory requirements, airports must ensure that ARFF services are always available and reliable (Putra et al, 2023).

This includes ensuring that ARFF teams have adequate resources and meet the qualification and training requirements set by ICAO and national aviation regulators (Trefný et al., 2022).

Furthermore, improvements in technology have made firefighting operations at airports and other places more effective (Vajdová et al., 2019). Working together and training fire and rescue teams well is crucial while using better rules and equipment. This way, we can reduce the harm caused by emergencies and keep airports and their surroundings safe(Tobisová et al., 2018). Thus, ARFF is vital in maintaining aviation safety and aiding passengers and aircraft crew in emergencies. Apart from the competency of the ARFF team, airports must also have an Airport Emergency Plan (AEP). The AEP contains detailed information about emergency response procedures for various types of emergencies, such as aircraft accidents, natural disasters, terrorist attacks, and hazardous material spills. The AEP outlines the roles and responsibilities of various parties involved in emergency response, including airport management, airline representatives, fire and rescue services, law enforcement agencies, and medical personnel (ICAO, 2013; ICAO Doc. 9137 Part 1, 2014; ICAO Doc. 9137 Part 7, 1991). To meet the competency needs of ARFF personnel and implement the AEP, Aircraft Rescue and Firefighting (ARFF) training facilities are required. These facilities are specialized centers that train airport firefighters to respond to aircraft emergencies (Jeffrey C. & Jeffrey S., 2016). ARFF training facilities provide realistic training scenarios that allow firefighters to practice their skills and prepare for real-life emergencies. These facilities typically include aircraft replicas complete with engines and other components, fuel spill areas and other properties designed to simulate various emergencies. The facilities have special firefighting equipment like foam trucks, dry chemical fire extinguishers and feature control towers or observation areas where instructors can monitor training exercises.

This research addresses a critical gap in Airport Rescue and Fire Fighting (ARFF) training, specifically focusing on developing the Fuel Distribution System(Rumizen, 2021) in ARFF trainers used in aircraft engine replicas. While there are two primary types of ARFF trainers, one using Flammable Liquid Hydrocarbons (FLH)(Sheet, 2021) and the other using propane as their training fuel(Frolov et al., 2017) changes in environmental regulations have presented new challenges. Stricter air and water quality regulations have made it increasingly difficult for ARFF personnel to receive high-quality firefighting training while maintaining compliance. Additionally, these environmental regulations have significantly driven up the operational costs of training facilities using liquid hydrocarbon fuels, leading some facilities to either cease operations or switch to propane-based systems (Bagot et al., 2021). This study contributes to the field by presenting research results demonstrating a marked improvement in reducing operational fuel consumption and minimizing the generation of environmentally hazardous byproducts within ARFF training facilities(Warneke et al., 2023; Zavila et al., 2016, 2019; Zavila & Chmelík, 2017).

The ARFF trainer consists of three main components: the control and observation building, the Specialized Aircraft Fire Trainer (SAFT), and the maneuver area with the fuel spill fire trainer. The SAFT comprises a modified Boeing 737 aircraft model, measuring 75 feet long, capable of simulating dozens of aircraft fire scenarios, both inside and outside, generated by computer systems. This system can be quickly shut down in emergencies or in the event of malfunctions, but further evaluation is required improve fuel efficiency(Patle et al., 2014). In alignment with this, ARFF trainers are typically provided by airports or training institutions primarily for competency requirements. However, for full-scale exercises in implementing the Airport Emergency Plan (AEP), ARFF trainers are typically represented by solid material stacks. There is a need for ARFF trainers with enhanced fuel efficiency in these scenarios (Sampey, 2013).

Politeknik Penerbangan Palembang, a vocational education institution under the Ministry of Transportation, plays a crucial role in preparing ARFF personnel as part of the aviation workforce. In providing competency training for the Aviation Firefighting and Rescue Diploma program and initial ARFF training, the institution already possesses an ARFF trainer. However, initial observations in this research revealed a significant operational fuel consumption. Observations indicated inefficiencies in fuel distribution and centralized control, making it challenging for operators, instructors, and teachers to select scenarios. Based on this background, this research aims to develop a Fuel Distribution Controller for the ARFF Trainer to enhance the efficiency of practical training in aircraft firefighting operations. This initiative addresses the need for more effective fuel management and scenario selection, ultimately improving the training experience for ARFF personnel.

Method

In this research, we have adopted an adapted version of the Research and Development (R&D) model initially proposed by Borg and Gall(Amalia et al., 2022).While the traditional R&D model comprises ten distinct steps, we have recognized the necessity for a more streamlined and flexible approach that aligns with the evolving landscape of research methodologies and the specific requirements of our study. This adaptation has been informed by the changing needs of research practices and is supported by insights from other researchers (Aka, 2019; Gustiani, 2019).Our adapted model condenses the ten original steps of the R&D process into three core stages: preliminary study, research development, and Validation. This adjustment was made to enhance the efficiency and effectiveness of our research activities while maintaining the scientific rigor necessary for robust research outcomes(Sugiono, 2005, 2014). The model recognizes that in the rapidly evolving field of research, flexibility and adaptability are essential. By taking this approach, we aim to address the unique demands of our research while ensuring that the scientific principles underpinning our methodology remain intact. This adaptation allows us to navigate the complex landscape of modern research, providing a structured yet adaptable framework to guide the creation and Validation of new products in a way that maximizes the impact of our research endeavors. It is a response to the ever-changing needs and methodologies of the research community, enabling us to stay at the forefront of scientific inquiry.

This research project commences with a structured approach that includes observations and interviews involving professionals from Politeknik Penerbangan Palembang, who are recognized experts from the industrial sector. Additionally, cadets, who serve as end users in the learning process, are interviewed to gain comprehensive insights. The goal of these interviews is to measure various factors crucial to the development of the Fuel Distribution Controller for the ARFF Trainer. To maintain consistency and guide these interviews, an interview guide is employed to ensure that specific areas of interest are covered. Sample questions in the interview guide include inquiries about the current operational challenges faced by ARFF trainers, their experiences with existing systems, their expectations for improvements, and their perceptions of the environmental impact. These insights serve as the foundation for designing a solution that truly enhances the efficiency of practical training in aircraft firefighting operations and addresses the identified needs.

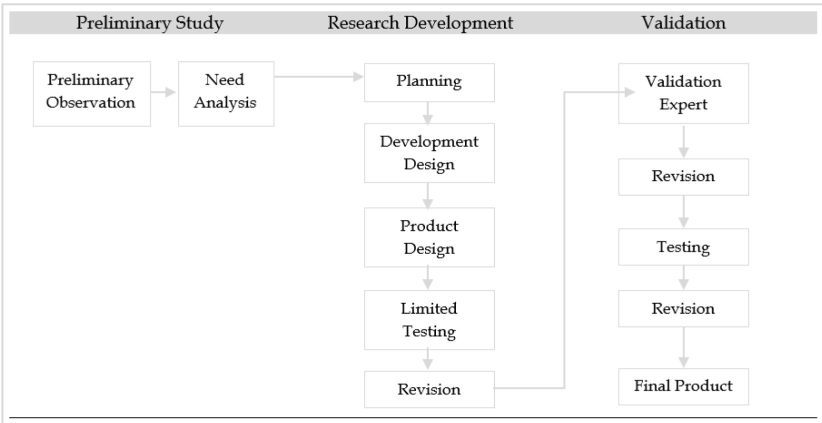

Figure 1. Conceptual Framework

Results and Discussions

Regarding the design of the fuel distribution controller for the ARFF Trainer, the researchers conducted interviews with professionals from Politeknik Penerbangan Palembang to understand the aircraft trainer's operational and maintenance procedures. The standard operating procedures for maintenance management are outlined in AC 150/5220-17B, which pertains to various types of Aircraft Rescue and Fire Fighting (ARFF) Training Facilities. To prevent damage, Politeknik Penerbangan Palembang performs monthly inspections to ensure the readiness of the ARFF trainer (Seung et al., 2014).From the interviews, it was found that the existing ARFF trainer comprises the following components: Burn Area Structure, Vehicle Maneuvering Area, Aircraft Mock-up, Control Station, and Support Systems. Among these components, three were identified as problematic in their operational implementation, namely the aircraft mock-up, control station, and support system. In the aircraft mock-up(Hutapea et al., 2023; Pan et al., 2023), where ignition points are located at various positions for ignition, there was an issue with immediate ignition. This was due to the ignition spark being too far from the propane gas produced(Gómez Montoya et al., 2018). The main reason for this was that the propane gas couldn't accumulate but was released immediately. It required a gas collection material to accumulate enough quantity for the spark from the spark plug (Lyle et al., 2007).Another noteworthy aspect from the interview results is the Control Station, a system that enables operators to configure and control real combustion exercises in the training facility. The control station can use either manual or automatic control systems to manage simulation variables. The challenge here is that both manual and automatic systems can only be operated from one location (the watchroom), which is situated on the second floor of the PPKP Politeknik Penerbangan Palembang building. This limitation has caused difficulties for instructors in the practical operation. Therefore, there is potential for a new design to address this issue. An intelligent control system for a fire control and burning training laboratory was presented, which includes a gas supply area, a flow-pressing area, burning area, and a control area (Chamorro-Atalaya et al., 2021).

Support Systems consist of functional units necessary for the proper functioning of the training facility and the simulation of various types of aircraft fires(Adu et al., 2018). Each support system comprises supporting components that form the system (for example, a fuel distribution system includes storage tanks, pumps, related pipes, etc.). This section is critical in determining the magnitude and quantity of fuel consumption. Due to the considerable distance between the fuel supply and the aircraft mock-up, a significant amount of fuel is required, which poses a challenge for operators during operations because of the limited fuel supply. Moreover, the automatic valve, which controls the fuel output(Rumalutur et al., 2020; Sari & Utama, 2021), is also located in a difficult-to-reach position, making maintenance or repairs challenging. The spray nozzles (spuyer) also play a crucial role in determining the realism of the generated flames and the quantity of fuel used in the simulation. Additionally, the phase changes in liquid fuel spray flames represent the primary mode of energy conversion in many high-power-density practical combustion devices (Wang et al., 2020).In essence, understanding how the phase of liquid fuel spray flames changes is crucial for realistic fuel combustion simulations.

On the positive side, the utilization of the Fuel Distribution Controller for the ARFF Trainer has proven to be a transformative addition to aviation firefighting training. It simplifies and accelerates training operations while simultaneously achieving a remarkable reduction in fuel consumption. This dual achievement not only enhances the efficiency of training exercises but also aligns with sustainability goals, an increasingly vital consideration in today's training scenarios. One notable aspect is the synergy between the Fuel Distribution Controller and Project-Based Learning(Chen et al., 2022; Helle et al., 2006). This approach, where cadets engage in hands-on, experiential learning, has seen significant benefits. The incorporation of the Fuel Distribution Controller enriches the learning experiences of cadets by fostering their creativity and deepening their understanding of aviation firefighting practices. The ability to engage with a realistic fuel fire scenario, controlled by the Fuel Distribution Controller, empowers cadets to gain practical insights and develop critical skills. Our findings, derived from a combination of observations and interviews, further emphasize the remarkable benefits of this technology. Notably, the Fuel Distribution Controller has demonstrated a substantial reduction in fuel consumption during training exercises, aligning with sustainable and cost-efficient training objectives. This outcome echoes the research findings of Jubiao et al. (2010), Sielegar and Self (2015), and Zhou and Zhang (2012), which highlight the significance of optimizing fuel use in aviation training. Moreover, the Fuel Distribution Controller has untapped potential as an educational resource. It can be seamlessly integrated into cadet lectures and training sessions to enhance their understanding and foster a more innovative and engaging learning atmosphere. This aligns with the educational principles of active and experiential learning, providing cadets with a hands-on experience that reinforces theoretical knowledge. The study conducted by R.S. (2018) supports this approach, indicating that practical, hands-on learning enhances comprehension and retention.(R.S., 2018). (Jubiao et al., 2010; Sielegar & Self, 2015; Zhou & Zhang, 2012)

As a result, we've created a fuel distribution controller for the ARFF Trainer device, a hands-on tool for aircraft firefighting training. This upgrade enhances the existing ARFF Trainer at Politeknik Penerbangan Palembang. We've made it user-friendly by developing an Android-based control system that connects via Wi-Fi (IoT pairing)(Ehsan et al., 2022; Li et al., 2014; Singh, 2023). This means easy online access from anywhere, anytime. Our goal is to make it simple for teachers, instructors, and students to operate and maintain the system, providing a more realistic, efficient, and cost-effective learning experience worldwide. This device focuses on two main parts: the Control Station and Support System. The Control Station allows operators to set up and manage real fire training exercises safely. It's transformed from a fixed unit to a mobile one, including:

Mobile Container

Central to the design and functionality of the Fuel Distribution Controller for the ARFF Trainer is the specially crafted Mobile Container. This ingeniously engineered container serves as the core of the entire system, embodying both compactness and organization to house all the essential components required for seamless operation. Within the Mobile Container, one finds a well-thought-out arrangement that optimally accommodates vital elements such as fuel storage, pumps, control systems, and distribution mechanisms. Each of these critical components has its designated space, ensuring that the entire system is meticulously organized for streamlined operations. The container is partitioned into five distinct compartments, and each compartment is carefully configured to serve a specific purpose, enhancing accessibility and operational efficiency. This meticulous organization significantly contributes to the user-friendliness of the system.

Trainers and operators will find it effortless to access and set up the equipment for training exercises. The clarity and ease of use afforded by the segmented compartments mean that trainers can swiftly access the components they need, reducing setup time and ensuring the training sessions run smoothly. The mobility offered by the Mobile Container is a game-changer in the context of aviation firefighting training. This portability allows trainers to easily transport the system to different training locations, adapting to various scenarios and training environments. Such flexibility ensures that the training can be tailored to meet specific objectives and that it can be conducted in diverse settings. In conclusion, the Mobile Container is a remarkable feat of engineering within the Fuel Distribution Controller for the ARFF Trainer. Its clever organization, compact design, and mobility enhance the system's user-friendliness, making it an invaluable tool for trainers and instructors. This component reflects a commitment to efficiency and adaptability, qualities that are essential in the dynamic field of aviation firefighting training."

Figure 2. Design of Fuel Distribution Controller for the ARFF Trainer

Electrical System

The Electrical System within the Fuel Distribution Controller for the ARFF Trainer device stands as a critical cornerstone of the entire setup. This system is meticulously designed and rigorously integrated to ensure uninterrupted and reliable operation. Serving as the powerhouse, it assumes the pivotal role of providing the essential electrical supply to all critical components, making it a linchpin of the system's functionality. One of the core responsibilities of the Electrical System is to ensure that every element of the Fuel Distribution Controller operates with precision and consistency. The electrical supply it provides powers a multitude of components, ranging from control systems to distribution mechanisms and beyond. This level of integration and power management is essential to maintain the system's efficiency and effectiveness, especially during intensive training exercises. A testament to the technical precision of this system is the meticulously designed electrical diagram. This diagram offers a visual representation of the intricate electrical connections and components, creating a roadmap that guides the operation of the entire system. It serves as a critical tool for both understanding the system's inner workings and ensuring its optimal functionality. In essence, the Electrical System within the Fuel Distribution Controller for the ARFF Trainer device epitomizes the commitment to operational reliability and technical excellence. By providing a steady and robust electrical supply to all critical components and offering a clear visual guide through the electrical diagram, it underlines the system's efficiency and dependability. This precision and technical acumen are invaluable in the context of aviation firefighting training, where safety and accuracy are paramount."

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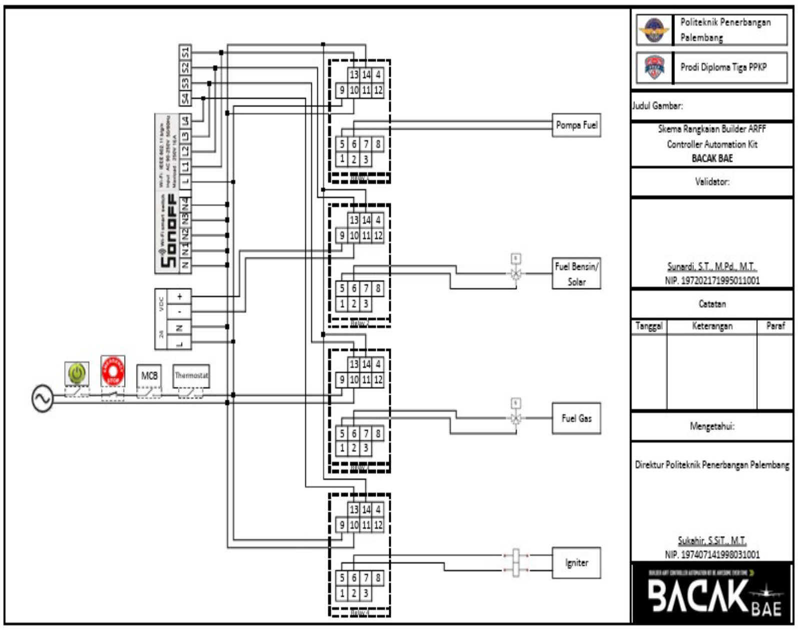

Figure 3. Electrical System of Fuel Distribution Controller for the ARFF Trainer

Control System

The Control System within the Fuel Distribution Controller for the ARFF Trainer is a vital component that orchestrates and supervises all critical operations. It is a sophisticated and versatile system designed to ensure the seamless functioning of the entire setup. This Control System is built on a dual approach, integrating both a manual control system and an Android-based Internet of Things (IoT) application. The manual control system serves as a dependable backup and provides an alternative means of operating the Fuel Distribution Controller. It is engineered to offer control through relay switching, enhancing the system's reliability and robustness. This manual control system is an essential fail-safe mechanism to ensure that operations can continue even in the event of technological glitches or unexpected situations. The second facet of the Control System is an innovative Android-based IoT application(Amalia, Nugraha, et al., 2022; Taufiq et al., 2016). This application is developed to offer operators a user-friendly and efficient means of controlling the Fuel Distribution Controller remotely(Saloni, S., & Hegde, 2016). It leverages the power of the Internet of Things, allowing operators to oversee and manage operations from anywhere with a connection to the internet(Cui, W., Du, C. & Chen, 2019). This level of remote control and accessibility is a significant advancement, enhancing the efficiency and convenience of using the system. One notable aspect of the Control System is its integration of the eW-Link application and Sonoff smart Wi-Fi switching devices. The eW-Link application is a pivotal element, facilitating seamless communication and control of the Fuel Distribution Controller. It provides operators with a user-friendly interface to monitor and adjust various parameters, ensuring that the system operates optimally. The Sonoff smart Wi-Fi switching devices are instrumental in providing wireless control capabilities. These devices, known for their reliability and robust performance, enable remote switching and monitoring of critical functions. Their integration with the Control System enhances the overall efficiency and accessibility of the Fuel Distribution Controller. In summary, the Control System within the Fuel Distribution Controller for the ARFF Trainer is a technologically advanced and comprehensive solution. It merges a dependable manual control system with a cutting-edge Android-based IoT application, providing operators with flexible and efficient control options. The inclusion of the eW-Link application and Sonoff smart Wi-Fi switching devices underscores the system's commitment to delivering reliable, user-friendly, and remotely accessible control of critical operations."

Pump and Distribution System

The Pump and Distribution System is an integral component of the Fuel Distribution Controller for the ARFF Trainer, serving a pivotal role in ensuring the effective delivery of Fuel Liquid Hydrocarbon (FLH) fuel to the Boeing engine trainer. This system is engineered to generate the necessary pressure to produce a controlled and pressurized fuel fire, a fundamental requirement in aviation firefighting training scenarios. One of the key functionalities of the Pump and Distribution System is to create the requisite pressure for simulating a realistic fuel fire within the training environment. This process is vital for the training and assessment of aircraft firefighting personnel, allowing them to practice and refine their skills in responding to fuel-related fires effectively. By accurately replicating real-world conditions, this system enhances the training experience and contributes to the development of critical skills. Additionally, the Pump and Distribution System has a direct and significant impact on fuel efficiency. It is designed to optimize the delivery of FLH fuel, ensuring that the right amount is dispensed for each training exercise. This approach not only conserves valuable resources but also contributes to cost savings and sustainability, aligning with the growing emphasis on environmental responsibility in training exercises. Another noteworthy advantage of this system is its impact on the maintenance of the pneumatic valves employed for fuel distribution control. By efficiently regulating the flow of fuel, the Pump and Distribution System minimizes wear and tear on these critical components. This reduced strain translates into simplified and less frequent maintenance requirements, thus increasing the overall reliability and longevity of the system. In summary, the Pump and Distribution System is an essential element of the Fuel Distribution Controller. Its primary function is to ensure the delivery of FLH fuel at the appropriate pressure to create controlled fuel fires for aviation firefighting training. Moreover, it makes a significant contribution to fuel efficiency and eases the maintenance demands on the pneumatic valves. Through its multifaceted role, this system enhances training effectiveness, reduces operational costs, and underscores the commitment to both safety and sustainability in aviation firefighting training scenarios.

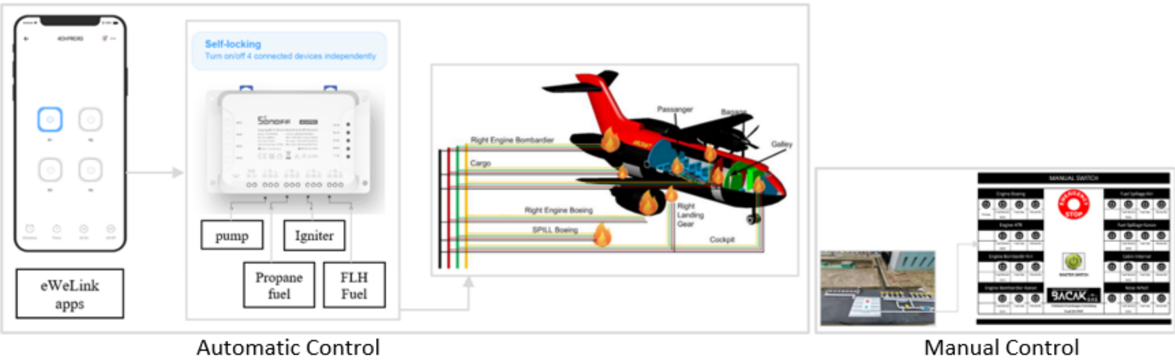

Figure 4. Control of Fuel Distribution Controller for the ARFF Trainer

Limited Testing

After the meticulous design phase of the Fuel Distribution Controller for the ARFF Trainer, a limited yet pivotal testing phase was initiated, involving cadets from the Diploma Three Program in Aircraft Rescue and Firefighting. The results of this testing phase stand as a testament to the remarkable efficiency and practicality of the system. One of the most striking achievements was the substantial reduction in fuel consumption. The original FLH (Fuel Liquid Hydrocarbon) tank capacity of 5,000 liters was significantly optimized, now requiring a mere 60 liters. Similarly, propane (LPG) usage underwent a remarkable transformation, reduced from 100 kg to just 15 kg. This remarkable efficiency underscores the exceptional utility of the Fuel Distribution Controller for ARFF Trainer, effectively curbing resource consumption and enhancing sustainability. Furthermore, the system's components underwent a notable reconfiguration for improved accessibility and maintenance. The pneumatic valve, previously situated inside the aircraft mockup, is now thoughtfully placed within a single mobile container. This relocation not only streamlines inspection and maintenance processes but also ensures the system's robustness and longevity. The control system itself has undergone a transformation, shifting from its original centralized location in the watch room to a more versatile setup. Now, it can be effortlessly operated from anywhere using the e-WeLink app on an Android device, facilitated by the SonOff smart switching technology with Wi-Fi pairing. This enhanced control system offers unprecedented flexibility and convenience. A significant indicator of the system's improved efficiency lies in the performance of the flow meter. Initially, a mere 22 liters of FLH was detected, assuming it had to fill the empty pipeline. During the critical first three minutes of firefighting (encompassing the pre-burn, full fire, and post-fire phases), the flow meter displayed a total consumption of 27 liters. This implies that only approximately 5 liters of fuel were utilized for extinguishing the fire. This dramatic reduction in fuel consumption and improved firefighting efficiency stands as a testament to the ingenuity of the system's design and its successful implementation. Several factors contribute to this enhanced fuel efficiency, as highlighted in previous studies. The reduction in the length of the pipeline(Kirk & Logan, 2015; Sielegar & Self, 2015), as well as the size of the sprayer nozzle, plays a pivotal role in optimizing fuel consumption. Smaller nozzle openings release less fuel, generating a finer misty spray that results in a larger, more controlled flame(Kashkarov et al., 2018; Sharma et al., 2015; Wang et al., 2020). These improvements not only enhance the safety and effectiveness of firefighting but also underscore the positive environmental impact of the Fuel Distribution Controller.

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Design validation

Design validation is a crucial phase in the product development process. During this stage, the product design is meticulously assessed and verified to ensure that it aligns with the intended objectives and requirements(Abdullah et al., 2021; Koscielny et al., 2017). As highlighted by Abdullah in 2021, experts play a pivotal role in this validation process. Two experts, each specializing in their respective fields, meticulously evaluate the product using three key indicators to assess its suitability. These critical indicators encompass the evaluation of fuel efficiency, the ease of use and control, and the realism of output. The validation results obtained from these experts' assessments are then compiled and presented in a comprehensive manner in Table 1. This table provides a detailed breakdown of the scores awarded by the experts for each of the key indicators, allowing for a thorough understanding of the product's performance in each area. The culmination of this assessment reveals that the product, in this case, the Fuel Distribution Controller for the ARFF Trainer, has received an impressive average score of 4.704. This score translates to an impressive 94.08% in terms of its validation percentage. Such a classification unequivocally categorizes the product as 'very valid,' indicating that it surpasses the necessary criteria for suitability and functionality and does not necessitate any further revisions. This outcome underscores the successful and well-executed design of the product, setting it on a path for effective use and application.

Table 1. Results of The Validation

Indicator	Average	Percentage	Result
fuel efficiency	4,750	95,00	Very valid
easy to use and control	4,604	92,08	Very valid
realistic output	4,758	95,16	Very valid
Average	4,704	94,08	Very valid

Product Trials to Final Product

Once the product design has been validated by experts and received a 'very valid' classification, the next critical phase involves conducting extensive testing of the product. In this phase, a comprehensive assessment of the product's real-world performance is carried out. To achieve this, a group of 40 participants was carefully selected, representing a cross-section of basic and senior aircraft firefighting trainees from diverse airport units across Indonesia. These participants bring valuable practical insights to the evaluation process, considering their varying levels of experience and expertise in the field. To thoroughly gauge the practicality and effectiveness of the product's development, a structured questionnaire was administered to the participants. This questionnaire comprised 20 questions designed to cover a spectrum of vital aspects, including product feasibility, ease of operation and maintenance, fuel efficiency, and the realism of the fire output. The questions were thoughtfully crafted to elicit feedback on each of these crucial dimensions, ensuring a comprehensive evaluation. The valuable feedback and insights garnered from this extensive product testing and evaluation process are meticulously compiled and presented in Table 2. This table serves as a detailed repository of the evaluation results, offering a comprehensive overview of the product's performance in real-world scenarios. It provides a valuable source of information for further insights and decisions related to the product's development and potential refinements.

Table 2. Result of the Practicality Criteria

Indicator	Average	Percentage	Result
product feasibility	4,67	93,42%	Very practical
ease of operation and maintenance	4,59	91,75%	Very practical
fuel efficiency	4,69	93,80%	Very practical
the realism of the fire output	4,66	93,13%	Very practical
Average	4,65	93,02%	Very practical

The results of the response questionnaire, as presented in Table 2, provide compelling evidence of the remarkable practicality and efficacy of the Fuel Distribution Controller for the ARFF Trainer. With an impressive average rating of 4.65 and an overall percentage of 93.02% across the assessment indicators, this product has received substantial recognition for its practicality and user-friendliness. These outstanding findings strongly resonate with Butt and Rehman's (2010) emphasis on the profound significance of such accomplishments in the field of product development (Butt & Rehman, 2010; Leninkumar, 2017).However, it is essential to recognize that the implications of these results go beyond mere numerical ratings. They underscore the transformative potential of this innovative product. By effectively addressing the operational challenges encountered by ARFF trainers, the Fuel Distribution Controller has the capacity to streamline training activities, reduce fuel consumption, and create a more user-friendly environment for learners. These improvements are not only vital for enhancing the training experience but also hold the promise of long-term cost savings, a benefit that can significantly impact the financial sustainability of ARFF training facilities. In addition to its implications for ARFF training, this innovation can also be linked to safety in chemical processes. When chemical accidents occur, the release dynamics of hazardous substances depend on various factors, including the physical state of the substances involved. Understanding the properties of these releases and how they change under different conditions is crucial for managing chemical incidents (Brambilla & Manca, 2011). The Fuel Distribution Controller's ability to enhance safety, efficiency, and preparedness in the aviation firefighting sector sets a significant precedent for how research and innovation can drive substantial improvements in industry-specific training methods. While the practicality and efficiency of the Fuel Distribution Controller have been established through these findings, it is vital to consider the broader implications. These implications extend beyond the specific use case of ARFF training to encompass industrial and educational innovation. As ARFF personnel benefit from this product, its utility may inspire similar advancements in other professional training fields. The adaptable and user-focused nature of the controller opens the door to potential innovations in various educational settings. Looking ahead, the significance of these findings for future research and practice cannot be overstated. Researchers in the field of aviation firefighting and professional training should draw inspiration from this study to explore further avenues of innovation. The success of the Fuel Distribution Controller demonstrates that addressing specific operational challenges with tailored solutions can lead to transformative outcomes. Future research endeavors could focus on refining and expanding the capabilities of such innovations, contributing to the continued enhancement of aviation safety and firefighting training.

Conclusions

The Fuel Distribution Controller for the ARFF Trainer stands as a remarkable achievement in the realm of aircraft firefighting training. Through a comprehensive process involving professional consultations, this Android-based, IoT-integrated system successfully addresses operational hurdles, promoting operational efficiency and reducing fuel consumption. With expert validation and practical trials yielding consistently high scores, it attains over 90% in terms of practicality and usability, reaffirming its excellence. This cutting-edge solution offers not only user-friendly attributes but also a cost-effective approach, thus closely aligning with its intended mission. The transformative power of this innovation has the potential to reshape and elevate aircraft firefighting training globally, serving as a testament to the significance of research and innovation in surmounting real-world challenges and fostering tangible advancements in professional training and education.

References

Abdullah, A., Nugraha, W., Sutiyo, S., Setiawan, R. F., Saputra, M. I. D., & Putra, R. P. (2021). Learning Media Development: FireDroid Application Base on the Android System and Distance Learning. *Journal of Airport Engineering Technology (JAET)*, *2*(01), 33–39. https://doi.org/10.52989/jaet.v2i01.47

Adu, C. H., Ahlijah, B. K., Otoo, S., Gakpey, V. S., Omane, M. M., & Out, I. (2018). Rescue and firefighting services: How can you plan for a better service and run an emergency exercise that really tests contingencies? *Journal of Airport Management*, *12*(3).https://hstalks.com/article/2354/rescue-and-firefighting-services-how-can-you-plan-/

Aka, K. A. (2019). Integration Borg & Gall (1983) and Lee & Owen (2004) models as an alternative model of design-based research of interactive multimedia in elementary school. *Journal of Physics: Conference Series*, *1318*(1). https://doi.org/10.1088/1742-6596/1318/1/012022

Amalia, D., Hadiansyah, R., & Septiani, V. (2022). Smart Parking IoT Based: Design and Prototype. *JMKSP (Jurnal Manajemen, Kepemimpinan, Dan Supervisi Pendidikan)*, *7*(1). https://doi.org/10.31851/jmksp.v7i1.6677

Amalia, D., Nugraha, W., Cahyono, D., Lestary, D., Septiani, V., & Rizko, R. (2022). *Developing a web-based simulator for safety management system training*. JPPI (Jurnal Penelitian Pendidikan Indonesia). http://dx.doi.org/10.29210/020232154

Bagot, Keith, & Hughes, W. J. (2021). Aircraft Rescue and Firefighting Training Fuel Comparative Evaluation. *The National Academies of Sciences, Engineering, and Medicine*, *2*.https://www.tc.faa.gov/its/worldpac/techrpt/artn01-4.pdf

Brambilla, S., & Manca, D. (2011). Recommended features of an industrial accident simulator for the training of operators. *Journal of Loss Prevention in the Process Industries*, *24*(4), 344–355. https://doi.org/10.1016/j.jlp.2011.01.009

Butt, B. Z., & Rehman, K. U. (2010). A study examining the student's satisfaction in higher education. *Procedia - Social and Behavioral Sciences*, *2*(2), 5446–5450. https://doi.org/10.1016/j.sbspro.2010.03.888

Chamorro-Atalaya, O., Arce-Santillan, D., Diaz-Leyva, T., & Diaz-Choque, M. (2021). Supervision and control by SCADA of an automated fire system. *Indonesian Journal of Electrical Engineering and Computer Science*, *21*(1), 92–100. https://doi.org/10.11591/ijeecs.v21.i1.pp92-100

Chen, S. Y., Lai, C. F., Lai, Y. H., & Su, Y. S. (2022). Effect of project-based learning on development of students' creative thinking. *International Journal of Electrical Engineering and Education*, *59*(3). https://doi.org/10.1177/0020720919846808

Cui, W., Du, C. & Chen, J. (2019). PSP: proximity-based secure pairing of mobile devices using WiFi signals. *Wireless Netw*, *25*, 733–751. https://doi.org/10.1007/s11276-017-1588-9

Ehsan, I., Mumtaz, A., Khalid, M. I., Iqbal, J., Hussain, S., Ullah, S. S., & Umar, F. (2022). Internet of Things-Based Fire Alarm Navigation System: A Fire-Rescue Department Perspective. *Mobile Information Systems*, *2022*. https://doi.org/10.1155/2022/3830372

Frolov, S. M., Aksenov, V. S., Ivanov, V. S., & Shamshin, I. O. (2017). Continuous detonation combustion of ternary "hydrogen–liquid propane–air" mixture in annular combustor. *International Journal of Hydrogen Energy*, *42*(26). https://doi.org/10.1016/j.ijhydene.2017.05.138

Gómez Montoya, J. P., Amador Diaz, G. J., & Amell Arrieta, A. A. (2018). Effect of equivalence ratio on knocking tendency in spark ignition engines fueled with fuel blends of biogas, natural gas, propane and hydrogen. *International Journal of Hydrogen Energy*, *43*(51). https://doi.org/10.1016/j.ijhydene.2018.10.117

Gustiani, S. (2019). Research and Development (R&D) Method as a Model Design in Educational Research and Its Alternatives. *Holistics Journal*, *11*(2), 12–22.https://jurnal.polsri.ac.id/index.php/holistic/article/view/1849

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education - Theory, practice and rubber sling shots. *Higher Education*, *51*(2). https://doi.org/10.1007/s10734-004-6386-5

Hutapea, R. E., & Martanti, I. F. R. (2023). Analysis of the Preparedness of Aircraft Rescue and Fire Fighting Officers in Overcoming Accidents and Fires at Adi Soemarmo Boyolali MAN Airport. *JETISH: Journal of Education Technology Information Social Sciences and Health*, *2*(2). https://doi.org/10.57235/jetish.v2i2.941

ICAO. (2013). *Annex 14 to the CICA 6th edition: Vol. I* (Issue July).https://store.icao.int/en/annexes?p=2

ICAO Doc. 9137 Part 1. (2014). *Airport Service Manual: Rescue and Fire Fighting*.https://store.icao.int/en/airport-services-manual-part-i-rescue-and-firefighting-doc-9137p1

ICAO Doc. 9137 Part 7. (1991). *Airport Services Manual: Airport Emergency Planning*.https://store.icao.int/en/airport-services-manual-part-vii-airport-emergency-planning-doc-9137p7

Jeffrey C., P., & Jeffrey S., F. (2016). Chapter 8 - Airport Safety Programs. *Practical Airport Operations, Safety, and Emergency Management, Butterworth-Heinemann*, 273–338. https://doi.org/10.1016/B978-0-12-800515-6.00008-1

Jubiao, Y., Keyu, J., & Chaoyi, Y. (2010). Analysis of lpg engine pid parameter control of transient air-fuel ration based on improved elman neural network. *Journal of Software*, *5*(1), 54–64. https://doi.org/10.4304/jsw.5.1.54-64

Kashkarov, S., Makarov, D., & Molkov, L. (2018). Effect of a heat release rate on reproducibility of fire test for hydrogen storage cylinders. *International Journal of Hydrogen Energy*. https://doi.org/10.1016/j.ijhydene.2018.04.047

Kirk, K. M., & Logan, M. B. (2015). Firefighting Instructors' Exposures to Polycyclic Aromatic Hydrocarbons During Live Fire Training Scenarios. *Journal of Occupational and Environmental Hygiene*, *12*(4), 227–234. https://doi.org/10.1080/15459624.2014.955184

Koscielny, G., An, P., Carvalho-Silva, D., Cham, J. A., Fumis, L., Gasparyan, R., Hasan, S., Karamanis, N., Maguire, M., Papa, E., Pierleoni, A., Pignatelli, M., Platt, T., Rowland, F., Wankar, P., Bento, A. P., Burdett, T., Fabregat, A., Forbes, S., … Dunham, I. (2017). Open Targets: A platform for therapeutic target identification and Validation. *Nucleic Acids Research*, *45*(D1), D985–D994. https://doi.org/10.1093/nar/gkw1055

Leninkumar, V. (2017). The Relationship between Customer Satisfaction and Customer Trust on Customer Loyalty. *International Journal of Academic Research in Business and Social Sciences*, *7*(4). https://doi.org/10.6007/ijarbss/v7-i4/2821

Li, S., Xu, L. Da, & Zhao, S. (2014). The internet of things: a survey. *Information Systems Frontiers 2014 17:2*, *17*(2), 243–259. https://doi.org/10.1007/S10796-014-9492-7

Lyle P., C., & Ahmad M., I. (2007). Performance of an unprotected steel structure subjected to repeated fire at a firefighter training facility. *Fire Safety Journal*, *42*(2), 81–90. https://doi.org/10.1016/j.firesaf.2006.06.009

Pan, W., Huang, Y., Yin, Z., & Qin, L. (2023). Optimal Collaborative Scheduling of Multi-Aircraft Types for Forest Fires General Aviation Rescue. *Aerospace*, *10*(9). https://doi.org/10.3390/aerospace10090741

Patle, D. S., Ahmad, Z., & Rangaiah, G. P. (2014). Operator training simulators in the chemical industry: review, issues, and future directions. *Reviews in Chemical Engineering*, *30*(2), 199–216. https://doi.org/10.1515/revce-2013-0027

Putra, J. V. C., & Rahimuddin, R. (2023). Analysis of the Role of the Airport Rescue and Fire Fighting Unit (ARFF) for Airside Safety at Adi Soemarmo Solo Airport. *International Journal of Religion Education and Law*, *2*(1), 55–68. https://doi.org/10.57235/ijrael.v2i1.322

R.S., U. (2018). Implementation of Project Based Learning in Learning Media Course in Mathematics Education Study Program. *Seminar Nasional Pendidikan Universitas PGRI Palembang*, 417–424.https://jurnal.univpgri-palembang.ac.id/index.php/Prosidingpps/article/view/1908

Rumalutur, S., Mappa, A., & Sianipar, E. P. (2020). Automatic Control System Charging Fuel Tanks and Monitoring Temperatures Using PLC. *Electro Luceat*, *6*(1). https://doi.org/10.32531/jelekn.v6i1.194

Rumizen, M. A. (2021). Qualification of Alternative Jet Fuels. *Frontiers in Energy Research*, *9*. https://doi.org/10.3389/fenrg.2021.760713

Saloni, S., & Hegde, A. (2016). WiFi-aware as a connectivity solution for IoT pairing IoT with WiFi aware technology: Enabling new proximity-based services. *In 2016 International Conference on Internet of Things and Applications (IOTA) IEEE.*, 137–142. https://doi.org/10.1109/IOTA.2016.7562710

Sampey, T. (2013). Preparing for large scale emergency events at airports. *Airport Magazine; AAAE Service Corporation, Incorporated*, *25*(5), 24–25, 27.http://www.airportmagazine-digital.com/airportmagazine/october_november_2013?pg=6#pg24

Sari, Z., & Utama, F. Y. (2021). Comparison of Fuel Consumption Testing Using Automatic Fuel Meter Trainer and Manual Measurement System. *Indonesian Journal of Engineering and Technology (INAJET)*, *3*(2). https://doi.org/10.26740/inajet.v3n2.p86-91

Seung, S. W., Hee, H. S., & Myung, Y. (2014). A Study on the Necessity and Contents of the Installation Criteria of the Fire Suppression Education & Training Facilities. *Fire Science and Engineering*, *28*(3), 72–79. https://doi.org/10.7731/KIFSE.2014.28.3.072

Sharma, P., Fagerlund, F., Iverfeldt, U., & Eskebaek, A. (2015). Fate and Transport of Fire-Born Particles in Porous Media. *Technologies*, *4*(1), 2. https://doi.org/10.3390/technologies4010002

Sheet, E. A. Eh. (2021). New Anti-knock Additives to Improve Gasoline Octane Number. *Journal of Petroleum Research and Studies*, *2*(2). https://doi.org/10.52716/jprs.v2i2.30

Sielegar, D., & Self, F. (2015). The pool fire case for pressure relief: Radiation exposure limited by fuel supply. *Process Safety Progress*. https://doi.org/10.1002/prs.11715

Singh, D. (2023). Internet of Things. In *Factories of the Future: Technological Advancements in the Manufacturing Industry*. https://doi.org/10.1002/9781119865216.ch9

Sugiono. (2005). *Memahami Penelitian Kualitatif*. Bandung: Alfabeta.

Sugiono. (2014). Metode Penelitian Pendidikan Pendekatan Kuantitatif Kualitatif dan R&D. *Bandung: Alfabeta.*

Taufiq, M., Amalia, A. V., Parmin, P., & Leviana, A. (2016). Design of Science Mobile Learning of Eclipse Phenomena with Conservation Insight Android-Based APP Inventor 2.*Jurnal Pendidikan IPA Indonesia*, *5*(2), 291–298. https://journal.unnes.ac.id/nju/index.php/jpii/article/view/7375

Tobisová, A., Mikula, B., Szabo, S., Blaško, D., Vajdová, I., Jenčová, E., Melníková, L., & Němec, V. (2018). The Simulation of Fire and Rescue Services Operations by Airplane Accidents. *2018 XIII International Scientific Conference - New Trends in Aviation Development (NTAD), Košice, Slovakia*, 144–149. https://doi.org/10.1109/NTAD.2018.8551636

Trefný, F., Capoušek, L., Kameníková, I., & Kameník, M. (2022). Optimization of Legislative Requirements for Heavy Equipment of Airport Rescue and Fire Fighting Brigade. *2022 New Trends in Aviation Development (NTAD), Novy Smokovec, Slovakia*, 237–241https://doi.org/10.1109/NTAD57912.2022.10013498

Vajdová, I., Mikula, B., Jenčová, E., & Mako, S. (2019). The Innovations Improving Fire Services at Airports. *2019 New Trends in Aviation Development (NTAD), Chlumec Nad Cidlinou, Czech Republic*, 198–203. https://doi.org/10.1109/NTAD.2019.8875589

Wang, Y., Taghizadeh, S., Karichedu, A. S., Kulatilaka, W. D., & Jarrahbashi, D. (2020). Piloted Liquid Spray Flames: A Numerical and Experimental Study. *Combustion Science and Technology*, *192*(10), 1887–1909. https://doi.org/10.1080/00102202.2019.1629431

Warneke, C., Schwarz, J. P., Dibb, J., Kalashnikova, O., Frost, G., Al-Saad, J., Brown, S. S., Brewer, W. A., Soja, A., Seidel, F. C., Washenfelder, R. A., Wiggins, E. B., Moore, R. H., Anderson, B. E., Jordan, C., Yacovitch, T. I., Herndon, S. C., Liu, S., Kuwayama, T., … Crawford, J. (2023). Fire Influence on

Regional to Global Environments and Air Quality (FIREX-AQ). *Journal of Geophysical Research: Atmospheres*, *128*(2). https://doi.org/10.1029/2022JD037758

Zavila, O., & Chmelík, R. (2017). Fire and false fire alarm causes in military jet aircraft of Czecho Slovakia and the Czech Republic. *Advances in Military Technology*, *12*(2). https://doi.org/10.3849/aimt.01193

Zavila, O., Chmelík, R., & Dopaterová, M. (2016). Statistics of aviation accidents and preconditions for aviation accidents in Czechoslovak and Czech military jet aircraft: Fire. *Advances in Military Technology*, *11*(2). https://doi.org/10.3849/aimt.01137

Zavila, O., Hocko, M., Buba, H., Slovackova, I., & Sudrychova, I. (2019). Analysis of aviation accidents associated with aircraft jet engine surge, on-board fire and crew ejection. *MOSATT 2019 - Modern Safety Technologies in Transportation International Scientific Conference, Proceedings*. https://doi.org/10.1109/MOSATT48908.2019.8944108

Zhou, Y., & Zhang, W. (2012). The Research of Aircraft Fuel System Fault Simulation Training System. *2012 IEEE International Conference on Automation and Logistics, Zhengzhou, China*, 484–488. https://doi.org/10.1109/ICAL.2012.6308229