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PLANNING TO OPTIMIZE CONDENSATION WATER FOR CLEAN WATER NEEDS AT THE AIRPORT

Akbar Nopriansyah Saputra[1], Fachrurrazi Burhanuddin[2]
[1]Directorate General of Civil Aviation, Nop Goliat Dekai Airport, Indonesia
[2]Department of Aerospace Engineering, University of Bristol, United Kingdom
*Correspondence e-mail: saputraakbarplg@gmail.com

Abstract

Condensation water from air conditioning can be used as an alternative water source because it still contains few minerals, has a low temperature, and maintains quality. However, until now, this condensation water has not been utilized for airport operational activities. This water could be used to water plants that have previously used up 5,000 liters of clean water. This research aims to design a water tank or reservoir for condensation water so that it is easy to distribute. The Research and Development method (R&D) using the 4D Model starts with definition (define), planning (design), development (develop), and dissemination (disseminate) limited to the design stage. The results of this study are presented in the form of a 3-dimensional design plan for a 50,000-liter condensation water storage system, equipped with a piping system, control tank, and pump to distribute the water. This study has received design validation from material experts and supervisors of the airport's mechanical unit. The validation results indicate a functional aspect assessment value of 77.5% (Good) and a quality aspect of 82% (Good), suggesting that further tank maintenance systems should be considered. Based on this assessment, the design of the condensation water optimization plan is deemed feasible for implementation.

Keywords: *Air Condition, Condensation Water, Planning, Optimization, Water Tank*

Introduction

Batam City is located in a tropical area with an average temperature of 24°C to 35°C and an average humidity of 76%, with the air getting hotter due to climate change (Ayunda et al., 2023). The Batam Business Entity Data for 2024 indicates that the rainy season lasts from November to April, while the dry season spans from May to October. The dry season can cause hot air to interfere with human activities, so an Air Conditioning System (ACS) is needed to cool the room, especially the Airport service room (Longhitano et al., 2024).

The air conditioning (AC) is the airport's mechanical equipment that regulates air temperature and humidity (Ma et al., 2023). Air circulation facilities, such as air conditioning (AC), fans, and air vents, are regulated in PM 38 of 2015, with a maximum temperature of 27 °C in the passenger terminal. In addition to regulating air temperature, this ACS also produces waste in the form of wastewater from the processing of the AC (Fahri et al., 2021). This AC can produce large amounts of wastewater, which is often disposed of through the AC wastewater pipe into the surrounding environment (Rezeki et al., 2022). This wastewater is produced from air that turns into dew particles, and the water vapor content drops when it reaches the dew point temperature, which lowers the relative temperature and creates AC water droplets (Nugraha et al., 2021).

(Fazal & Mataram, 2023) Hang Nadim Airport Batam provides eight air conditioning chillers and twenty-two air handling unit auxiliary systems capable of producing cool air (Rozi & Khuzaini, 2021). The author's observation results show that at Hang Nadim Airport, condensation air is still wasted and has not been utilized, despite the substantial amount. When in the field, the author once measured the amount of air discharge in the Air Handling Unit discharge pipe, which goes directly to the drainage, where the air discharge is approximately 25,000 liters per day. If we look at previous literature where AC air condensation can be used in plants (Nusa et al., 2025), this can cut maintenance costs and be more environmentally friendly (Fazal & Mataram, 2023). Waste and chemicals are generated from the airport and aircraft's construction, operation, and maintenance (Sulej-Suchomska et al., 2024). According to Government Regulation 40, 2012, it must be managed before being taken out of the airport, following the provisions.

(Eatoo & Mishra, 2024) Although the amount of AC wastewater is quite large, it is often disposed of through the AC wastewater pipe into the surrounding environment, wasting condensation water for nothing (Fahri et al., 2021). The study Eatoo & Mishra (2024), found that the condensation water from the AC is pure water due to condensation from the outside air. The impurity content only comes from the air and can be used; the condensation water is usually thrown away (Anak Agung, 2020). Therefore, its use as clean water for watering ornamental plants is one application of AC condensation. Watering plants with AC wastewater using a Water Flow sensor to measure the amount of water needed, which then triggers the Real Time Clock to open and release water from the Solenoid Valve (a controllable water tap) (Hossain et al., 2024). The large amount of condensation water produced at Hang Nadim Airport, Batam, can be used for watering plants and as a source of PPKP water, with a volume of 24,300 liters, specifically classified in class 9.

Based on this background, this study aims to design an AC condensation water optimization tool that supports safety at airports, positively impacts the environment and water efficiency, and serves as an innovation in airport maintenance management.

Methods

This research uses the 4D Research and Development (R&D) model methodology. The 4D Model is a research methodology designed to create, refine, and optimize a specific product or model that is effective, validated for reliability, and capable of implementation through a structured series of stages (Guslinda et al., 2024). There are four stages in the 4D Model, namely, the first stage is definition, the second stage is design, the third stage is development, and the fourth stage is dissemination (Sugiyono, 2015). This research is limited to the second stage, specifically the design stage, with a focus on prototype design.

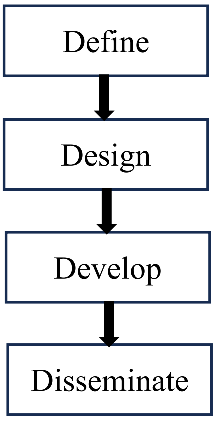


Figure 1. 4D Development Stage

This research was conducted at Palembang Aviation Polytechnic, and the supporting data were obtained from Hang Nadim International Airport during the author's on-the-job training. This research began with the Define stage to identify the product and its standards and requirements for development. During this stage, the project was divided into four key areas: Front-End Analysis, Subject Analysis, Quantity Analysis, and Formulation of the problem, all aimed at achieving success in researching innovations to optimize AC condensation water at the airport. Furthermore, the Design stage aims to continue the product planning stage. At this stage, work on the first product, an air condensation piping system for drainage direction, began, which was then continued with the product stage, resulting in well-distributed condensation water.

$$P = \frac{N}{f}\, x\, 100\%$$

Description:
P = Percentage
N = Score Obtained
F = Maximum Score

Table 1. Validation Criteria

Criteria	Category
84,01% – 100,00 %	Very Worthy
68,01 % – 84,00 %	Worthy
52,01 % – 68,00 %	Quite Worthy
36,01 % – 52,00 %	Unworthy
20,00 % - 36,00 %	Very Unworthy

Source: (Saputra et al., 2023)

Assessment of expert validation analysis with the quantitative method using equation and table assessment, as shown in Table 1. This research aimed to design the water distribution stage, which is ready to be used for the needs of watering plants at the airport.

Results And Discussions

After conducting an in-depth discussion, it was found that the design of AC condensation water utilization planning requires an integrated approach, taking into account factors such as the production capacity of AC condensation water, classification of condensation water, water requirements for watering plants and other water requirements (Indaryanti et al., 2025). That can be diverted and efficiency of water use based on the Research and Development (R&D) research design, with a 4D model with four stages starting from the first stage of define, design, develop, and finally disseminate, which is simplified to only a 2D model to produce a product and then test the effectiveness of the product (Indaryanti et al., 2025).

Conditions when conducting research on maintenance and care of mechanical units on AC at the airport, especially on the waste water plumbing system on the Air Handling Unit (AHU), where the system still directs waste water directly to the drainage flow or is wasted as depicted in the layout in Figure 2.

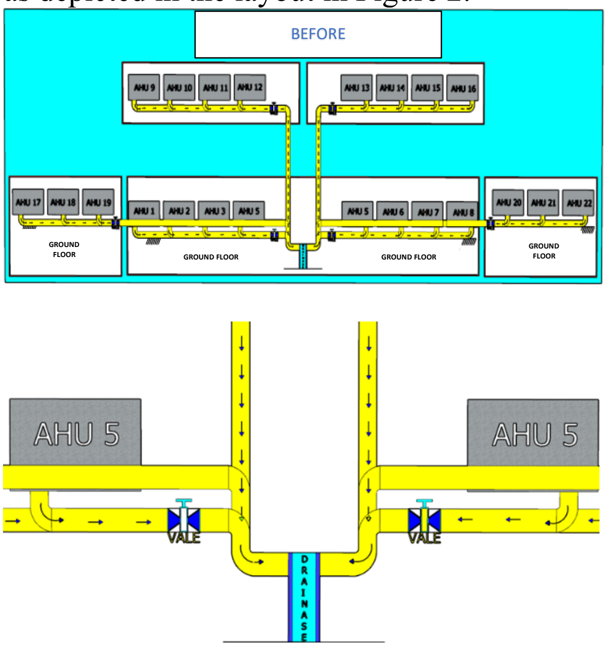


Figure 2. Previous Layout
(Source: Hang Nadim International Airport)

This is the reference for researchers to develop an innovation system that focuses on optimizing condensation water for watering plants (Sunaryanti et al., 2022). This planning is done so that the airport can utilize condensation water for watering plants and distribute it to meet the airport's water needs, after identification in the previous stage and collection of data obtained from observations. Researchers obtain information on the data collected in the form of condensed water produced and needed, as well as the classification of the water's quality to ensure it is suitable for plants.

In the calculation of condensation water, it is necessary to measure the condensation water discharge in AHU with a capacity of 30 PK Model MAC 300 YORK. The researcher did this by collecting condensation water in each exhaust duct in 22 AHU units at Hang Nadim International Airport which produces 1.2 liters/minute, which is obtained from: 1.2 liters/minute x as long as the water is produced.
Example on AHU 1
DIK: 1.2 liters/minute
1.2 × 60 = 72 liters/hour
The running hours of AHU 1 one day are 15 hours
72 × 15 = 1,080 liters/day
The total discharge of wastewater produced is the amount collected every 25,178 liters per day. With this observation, the researcher found the results of the condensation water produced, which are listed in Table 2.

Table 2. Condensation Water Calculation Results

AHU	Running Hours	Running Days	Output Water/Day
1	05:00 - 20:00 WIB	S - M	1.080 L/day
2	06:30 – 20:00 WIB	S - M	972 L/day
3	05:00 – 20:00 WIB	S - M	1.080 L/day
4	06:00 – 13:30 WIB	S - M	542 L/day
5	04:00 – 19:00 WIB	S - M	1.080 L/day
6	04:00 – 19:00 WIB	S - M	1.368 L/day
7	05:00 – 20:30 WIB	S - M	1.476 L/day
8	06:00 – 18:10 WIB	S - M	876 L/day
9	04:00 – 20:00 WIB	S - M	1.512 L/day
10	07:00 – 19:00 WIB	S - M	864 L/day
11	05:00 – 20:00 WIB	S - M	1.080 L/day
12	05:00 – 20:00 WIB	S - M	1.080 L/day
13	05:30 – 19:00 WIB	S - M	994 L/day
14	06:30 – 18:30 WIB	S - M	900 L/day
15	04:50 – 20:00 WIB	S - M	1.575 L/day
16	04:50 – 20:00 WIB	S - M	1.575 L/day
17	OFF		
18	09:00 – 12:40 WIB	S - M	264 L/day
19	08:30 – 12:40 WIB	S - M	372 L/day
20	04:00 – 19:30 WIB	S - M	1.116 L/day
21	04:30 – 19:00 WIB	S - M	1.404 L/day
22	05:30 – 19:00 WIB	S - M	1.332 L/day
		Total	25.178 L/day

This reference is intended for researchers to develop a plan for optimizing condensation water so that it is more useful for watering plants, which is typically done every 2 days. Once the need for water usage reaches 5,000 liters, it can help meet the water needs at PKP-PK Hang Nadim Airport Batam, which falls under category 9 with a water requirement of 24,300 liters. The amount of condensation water wasted in this study necessitates a water tank specification that is sufficient to accommodate all the water in a single day. With 24,300 liters/day, the calculation is sufficient using the existing volume formula, which is twice the existing amount, as it avoids the overload that occurs. What is needed is a water tank in the form of a feeding tube that utilizes the tube volume formula.
V = π^2t
Description:
V = Volume
r = radius of Base Circle
t = Tube Height

So, with 50,000 liters of water, the water tank specifications are obtained with dimensions of 275 cm x 850 cm, so the volume of the tank is:
V = π^2t
= 3,14 $(1,375)^2$ x 8,5
= 3,14 (1,89) x 8,5
= 50,4 m^3 / 50.400 liters

The volume of the tank is 50.4 $m^{3,}$ which is used as needed. In this planning, a pipe is also required for the condensation water line to ensure proper operation. Here is the formula according to SNI 8153:2015:
$D_{opt} = 226 \times G^{0,5} \times p^{-0,35}$
Keterangan:
D_{opt} = Optimum Pipe Diameter (mm)
G = Mass Flow Rate (kg/s)

p = Density Solution (kg/m^3)
Water flow 1,2 liters/minute = 72.000 kg/h
G = 72.000 kg/h
= 20 kg/s
Over design = 10%
So, G_D= G + 10% G
= 72.000 kg/h + (10% x 72.000 kg/h)
= 72.000 kg/h + 7.200
= 79.200 kg/h
= 22 kg/s
p = 998,23 kg/m^3.

$$D_{opt} = 226 \times G^{0,5} \times p^{-0,35}$$
$$= 226 \times (22)^{0,5} \times (998,23)^{-0,35}$$
$$= 226 \times 4,69 \times 0,089$$
$$= 94,3 \text{ mm}$$
$$=3,71 \text{ inch}$$

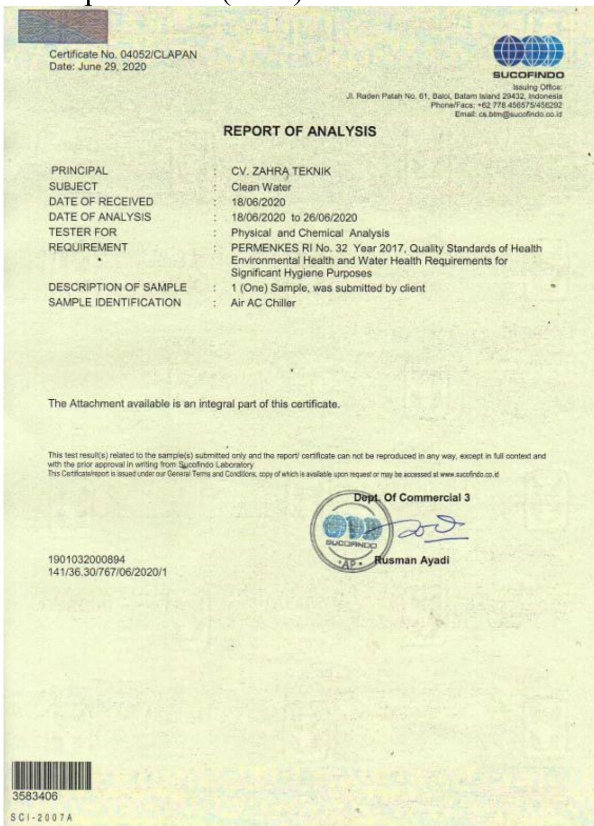
Based on these results, the following nominal equivalents for commercial pipe sizes are obtained.

(NPS)	= 100 mm	= 4 inch
Inside Diameter	= 100 mm	
Outside Diameter	=110 mm	

(Algarni & H. Mohamed, 2022) Designing the use of pumps only requires consideration of filling speed and efficiency (Lavrič et al., 2024). In this process, filling speed is the main factor to ensure that the time required to fill the tank or other systems can be shortened (Stanisavljević et al., 2021). Meanwhile, efficiency is an important criterion for reducing energy consumption and operational costs (Algarni & H. Mohamed, 2022). By considering these two aspects, it is expected that the designed pump-system can work optimally, save energy, and provide the best performance according to needs. Therefore, researchers use the specifications centrifugal pump that have been found in market as follows.

Voltage/Power	: 1.5 HP
Suction Haed (HS)	: 1,5 m
Total Haed (HS)	: 35 m
In/Out	: 2,5 Inch
Debit	: 300 L/minute
Tipe	: Centrifugal Pump

In the preliminary test on AC wastewater, it was carried out to determine the quality of the condensation water of Hang Nadim International Airport, where the water quality samples studied were compared with the quality standards in class IV based on PP No. 21 of 2021 concerning the Implementation of Environmental Protection and Management. Based on the results of the preliminary test, a follow-up test was conducted in the SUCOFINDO laboratory on parameters that exceeded the quality standard, specifically the nitrite parameter (NO2).


Certificate No. 04052/CLAPAN
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Phone/Facs: +62 778 456575/456292
Email: cs.btm@sucofindo.co.id

REPORT OF ANALYSIS

PRINCIPAL	:	CV. ZAHRA TEKNIK
SUBJECT	:	Clean Water
DATE OF RECEIVED	:	18/06/2020
DATE OF ANALYSIS	:	18/06/2020 to 26/06/2020
TESTER FOR	:	Physical and Chemical Analysis
REQUIREMENT	:	PERMENKES RI No. 32 Year 2017, Quality Standards of Health Environmental Health and Water Health Requirements for Significant Hygiene Purposes
DESCRIPTION OF SAMPLE	:	1 (One) Sample, was submitted by client
SAMPLE IDENTIFICATION	:	Air AC Chiller

The Attachment available is an integral part of this certificate.

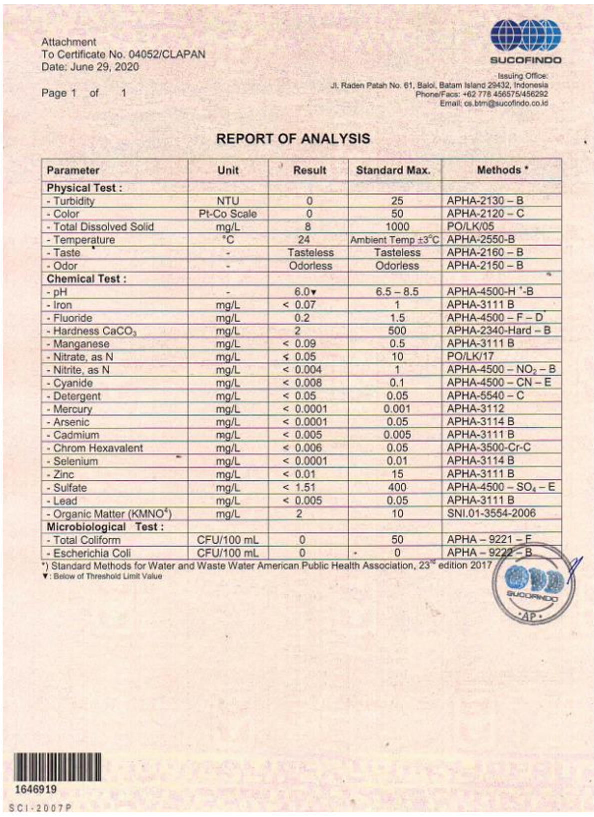
This test result(s) related to the sample(s) submitted only and the report/ certificate can not be reproduced in any way, except in full context and with the prior approval in writing from Sucofindo Laboratory
This Certificate/report is issued under our General Terms and Conditions, copy of which is available upon request or may be accessed at www.sucofindo.co.id

Dept. Of Commercial 3
Rusman Ayadi

1901032000894
141/36.30/767/06/2020/1

3583406
SCI-2007A

Figure 3. Report of Analysis
Source: SUCOFINDO



Attachment
To Certificate No. 04052/CLAPAN
Date: June 29, 2020

Page 1 of 1

SUCOFINDO
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Phone/Facs: +62 778 456575/456292
Email: cs.btm@sucofindo.co.id

REPORT OF ANALYSIS

Parameter	Unit	Result	Standard Max.	Methods *
Physical Test :				
- Turbidity	NTU	0	25	APHA-2130 – B
- Color	Pt-Co Scale	0	50	APHA-2120 – C
- Total Dissolved Solid	mg/L	8	1000	PO/LK/05
- Temperature	°C	24	Ambient Temp ±3°C	APHA-2550-B
- Taste	-	Tasteless	Tasteless	APHA-2160 – B
- Odor	-	Odorless	Odorless	APHA-2150 – B
Chemical Test :				
- pH	-	6.0▼	6.5 – 8.5	APHA-4500-H $^{+}$-B
- Iron	mg/L	< 0.07	1	APHA-3111 B
- Fluoride	mg/L	0.2	1.5	APHA-4500 – F – D
- Hardness $CaCO_3$	mg/L	2	500	APHA-2340-Hard – B
- Manganese	mg/L	< 0.09	0.5	APHA-3111 B
- Nitrate, as N	mg/L	< 0.05	10	PO/LK/17
- Nitrite, as N	mg/L	< 0.004	1	APHA-4500 – NO_2 – B
- Cyanide	mg/L	< 0.008	0.1	APHA-4500 – CN – E
- Detergent	mg/L	< 0.05	0.05	APHA-5540 – C
- Mercury	mg/L	< 0.0001	0.001	APHA-3112
- Arsenic	mg/L	< 0.0001	0.05	APHA-3114 B
- Cadmium	mg/L	< 0.005	0.005	APHA-3111 B
- Chrom Hexavalent	mg/L	< 0.006	0.05	APHA-3500-Cr-C
- Selenium	mg/L	< 0.0001	0.01	APHA-3114 B
- Zinc	mg/L	< 0.01	15	APHA-3111 B
- Sulfate	mg/L	< 1.51	400	APHA-4500 – SO_4 – E
- Lead	mg/L	< 0.005	0.05	APHA-3111 B
- Organic Matter ($KMNO^4$)	mg/L	2	10	SNI.01-3554-2006
Microbiological Test :				
- Total Coliform	CFU/100 mL	0	50	APHA – 9221 – E
- Escherichia Coli	CFU/100 mL	0	0	APHA – 9222 – B

*) Standard Methods for Water and Waste Water American Public Health Association, 23rd edition 2017
▼: Below of Threshold Limit Value

SUCOFINDO
AP

1646919
SCI-2007P

Figure 4. Laboratory Results SUCOFINDO
Source: SUCOFINDO

Based on the observations of physical and chemical parameters related to the quality of condensation water during the research, the following results were obtained.

Table 3. Parameters

No	Parameters	Unit	Result	Quality std	method
1	Temperature	^{o}C	24	±3^{o}C	APHA-2500-B
2	Alkalintas	Mg/L	2	100	APHA-2120-C
3	Color	Mg/L	0	50	APHA-C
4	PH	Mg/L	6.0	6.0 – 8.5	APHA-4500-H+B
5	Organic Matter	Mg/L	2	10	APHA-311-B
6	Total Coliform	Mg/L	0	50	APHA-4500-E

Next, design a water tank to store condensation water, which will later be used for watering plants and other water needs at the airport.

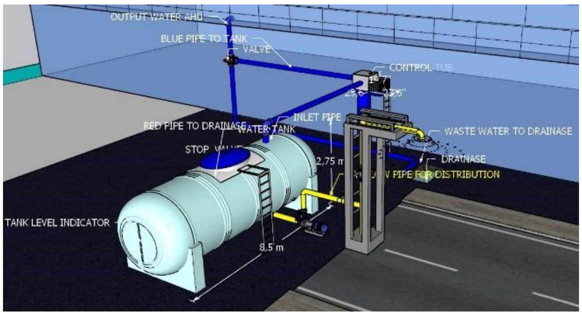

Figure 5. Product Design

Explanation of innovation in the product design plan for the reservoir and pipeline. Water tank, which functions to accommodate AC condensation water before being continued for watering (Minarni et al., 2023). A water tank with a capacity of 50,000 liters is large enough to store a significant amount of condensation water, which can accommodate all the condensation water produced in one day. The type of water tank is in the form of a tube that has no corners for easy maintenance, made of polyethylene or fiberglass because it is resistant to corrosion and chemicals and is lightweight and easy to install, UV resistant ensures that the tank is not easily damaged by direct sunlight and a lid with a lock to keep the water clean and free from contamination found in the marketing.

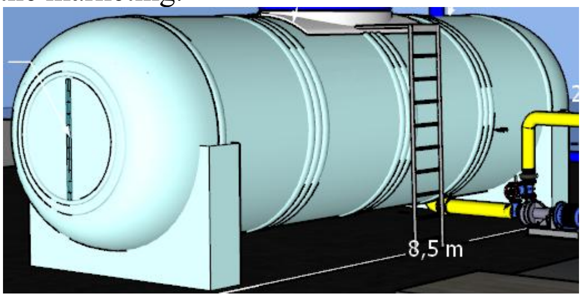

Figure 6. Water Tank Design

The output pipe from the AHU is channeled to the water tank and also routed to the drainage system after the water tank is full. The type of pipe used is PVC or PPR, chosen because it is durable, does not rust easily, and is easy to install. A diameter of 4 inches is sufficient to accommodate the required water volume for storage. The strength of PVC pipes can withstand pressures up to 10 bars.

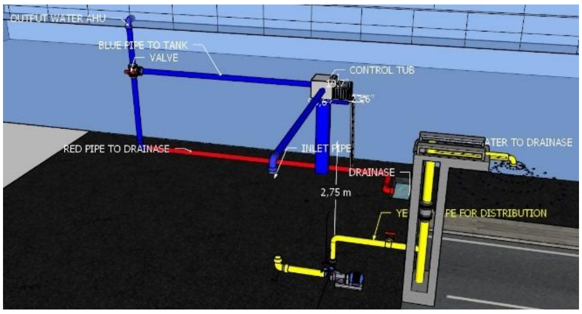

Figure 7. Piping Design

The pump functions to pump water from the water tank to the watering car. The pump used is a centrifugal pump because it has high efficiency and can be used for various clean water applications. The pump's power is 5.5 HP, which is sufficient for the industry to flow water at a rate of 300 liters per minute.

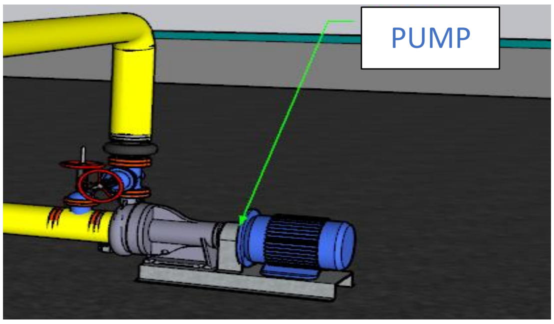

Figure 8. Pump Design

The condensation water storage system has several valves and types according to their respective functions to help make it easier to control the desired flow rate, here are some of these valves:

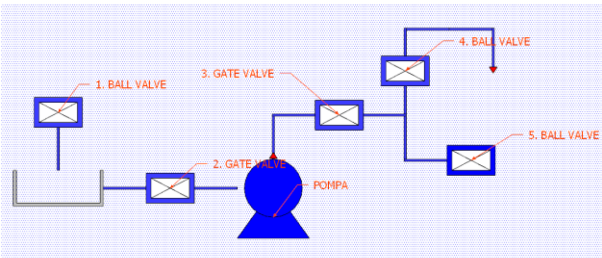

Figure 9. Blok System Valve

Description:
Valve 1 = Ball valve, water tank input
Valve 2 = Gate valve, water tank output
Valve 3 = Gate valve, output pump
Valve 4 = Ball valve, distribution 1
Valve 5 = Ball valve, distribution 2
The AHU output ball valve functions to open and close the flow of condensate water to the drainage system. This valve is used when filling condensation water into the water tank, allowing it to be accommodated and optimized properly.

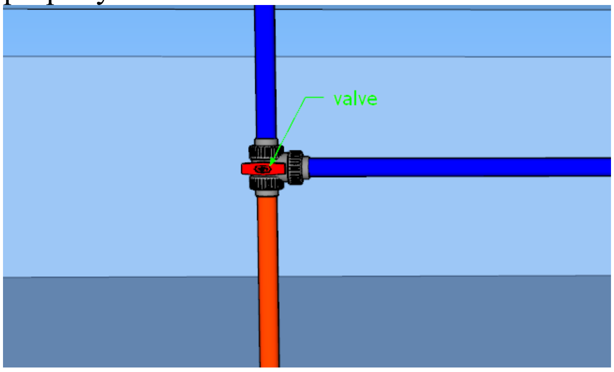

Figure 10. Ball Valve

The gate valve of the water tank output functions to regulate the flow from the pump, allowing the gate valve to be opened when water is needed, thereby controlling the flow of water according to the specific usage.

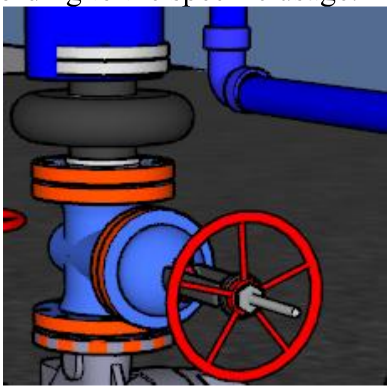

Figure 11. Gate Valve Output Water Tank Design

The main distribution valve uses a ball valve type valve, which functions to open and close the flow that will be distributed to the plant watering car.

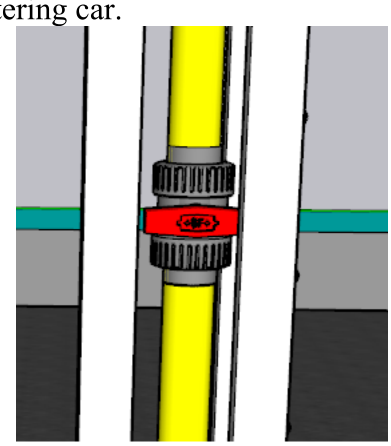

Figure 12. Main Distribution Valve

The second distribution valve is a ball valve that functions to facilitate distribution for other uses at the airport, such as rinse water, wash water and hydrant water.

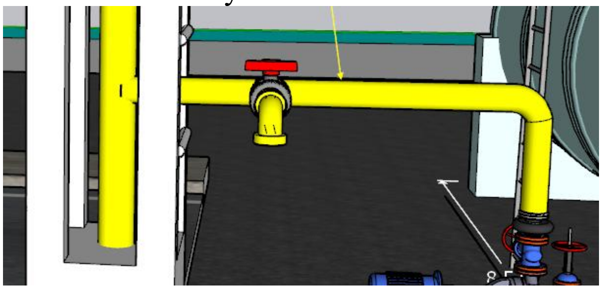

Figure 13. Second Distribution Valve

(Tiswan & Ramlan, 2018) The pipe from the water tank is pumped to flow to the watering car. This pipe is made by being accommodated using light steel so that the pipe remains sturdy and making it easier to fill the condensation water into the watering tank car (Tiswan & Ramlan, 2018).

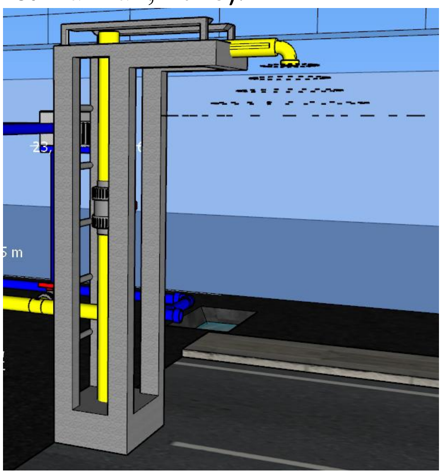

Figure 14. Filler Pipe Design

The stop valve functions to control the flow of water entering the water tank, so that when it is full, the flow of water automatically stops and prevents overflow.

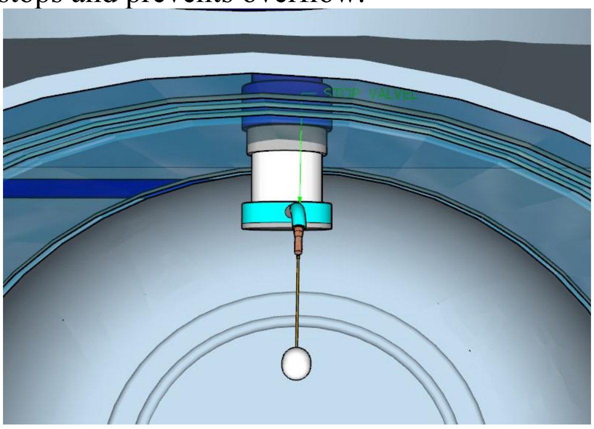

Figure 15. Stop Valve

The Control Tank is equipped with a filtration system that can capture sediment, debris, and other particles before the water is discharged into the holding tank (Akbar et al., 2022). The control tank provides an access point for maintenance personnel to inspect and clean.

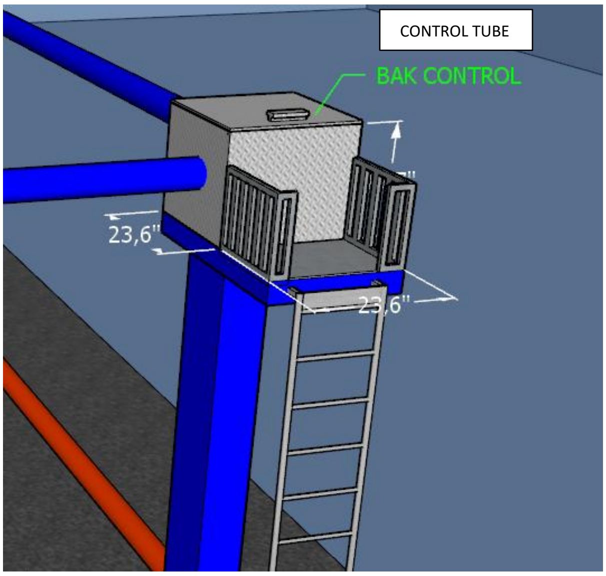

Figure 16. Control Tank

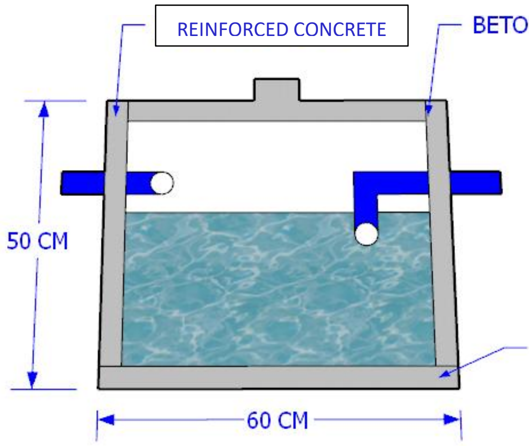

Figure 17. Control Tank Layout

The final stage involves validating the product design with provisions approved by supervisors, media experts, and material experts to obtain an instrument assessment as part of airport mechanical equipment maintenance management. The validity and application of the design are the subject of critical recommendations from experts carried out to ensure the feasibility of operational performance or data quality (Ramadhani et al., 2024). The following is the validation data:

1. Ir. Setiyo, M.M as a lecturer in Mechanical Engineering at Palembang Aviation Polytechnic.

2. Mochammad Hanif, S.ST as supervisor of Mechanical Equipment Maintenance Management at Hang Nadim International Airport.

Table 4. Validator

No	Name	Skill	Opinion
1	Ir. Setiyo, M.M	Tool Expert	Tools worth using
2	Mochammad Hanif, S.ST	Mechanical Equipment Maintenance Management	Tools worth using

Testing is carried out comprehensively to determine the performance and constraints of the tool and identify parts that need repair. Additionally, testing of the tool system is conducted to verify the performance of all tool components as expected.

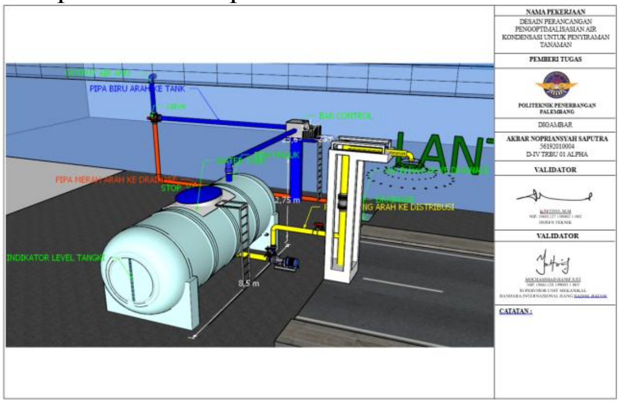

Figure 18. Design Validation Sheet

This assessment sheet is designed to gather information on the quality of the design for optimizing condensed water for Plant Watering at Airports. Information on the quality of this material is based on several aspects of Design quality (Adly et al., 2022).

Table 5. List of Assessment Aspects

No	Assessment Aspects	1	2	3	4	5
	A. Functional Aspect					
1	Utilization of condensation water for plant watering and other needs at the Airport					
2	The planned tank capacity meets the needs					
3	the use of piping systems has met the needs					
4	Utilities required to fill condensation water					
	B. Quality Aspects					
1	The quality of the condensation water meets the chemical parameter requirements					
2	The tank materials used have met the technical criteria					
3	The distribution system used has convenience					
4	The pump system has met the required criteria					
5	Ease of system maintenance					

Description:
5 = Very Good
4 = Good
3 = Sufficient
2 = Less
1 = Very Less

$$P = \frac{N}{f} x\ 100\%$$

Table 6. Validator Assessment 1

Aspect	Average Score
Funcion	75 %
Quality	76 %
Total Average	75,5 %

Table 7. Validator Assessment 2

Aspect	Average Score
Funcion	80 %
Quality	88 %
Total Average	84 %

Table 8. Total Rating

Aspect	Average Score	Description
Funcion	77,5 %	Good
Quality	82 %	Good

Condensation water with a volume of 25,178 liters per day yielded chemical parameter results that were feasible based on the Sucofindo test. It could be used for watering plants and meeting water needs at the airport. Researchers designed a condensation water reservoir with a capacity of 50,000 liters that could accommodate the amount of condensation water. This water tank is made of Polyethylene (PE) or fiberglass, which is resistant to corrosion and rust, and protects against UV rays. The design of the tank, which utilizes pumps, only requires consideration of filling speed and efficiency (Ivanly et al., 2023). In its mechanism, filling speed is the primary factor in ensuring that the time required

to fill the tank or other systems can be shortened. Meanwhile, efficiency is an important criterion for reducing energy consumption and operational costs. The designed pump system is expected to operate optimally, conserve energy, and deliver the best performance according to individual needs.

The final stage of this study, namely validation by material experts and field supervisors, was rated as Good. The results of the material expert analysis, carried out by the two validators, obtained an assessment of 77.5% (Good) for the function aspect and 82% (Good) for the quality aspect. Based on these values, the design of the air condensation optimization planning is feasible for use. A study on the utilization of air condensation from air conditioners at Hang Nadim Airport in Batam highlights its significant potential in reducing water wastage through more efficient management.

With a daily production capacity of 25,178 liters, the study recommends storing the condensed water in a 50,000-liter tank for use in watering plants around the airport area. The proposed tank design is cylindrical, made of lightweight materials such as polyethylene or fiberglass, ensuring durability, corrosion resistance, and easy installation. Additionally, a PVC or PPR piping system with a 4-inch diameter was selected to ensure optimal water flow. A centrifugal pump is also proposed to pump water into watering vehicles, aiming to improve water usage efficiency and minimize wastage.

The adoption of an air conditioning condensation utilization system for irrigation and other purposes at airports can reduce water consumption costs by utilizing water that would otherwise be wasted, thereby decreasing reliance on external water sources. While there is an initial installation cost, long-term savings on water and energy expenses can provide significant financial benefits. Environmentally, the system supports water conservation, reduces pollution and wastewater flow, and lowers the carbon footprint by optimizing existing resources. Additionally, this system can enhance the airport's image as an eco-friendly facility, potentially attracting customers, and government incentives are feasible to utilize.

Implementing an air conditioning condensation utilization system at airports can be cost-effective and environmentally beneficial, as it reduces water consumption and minimizes wastewater discharge, thereby contributing to sustainability efforts. However, some technical constraints and risks must be considered. One major concern is the potential for contamination, as condensation water may contain dust, bacteria, or other pollutants that could pose health risks if not properly filtered. To address this, a high-performance filtration and treatment system must be in place, which requires regular maintenance to ensure the system's effectiveness. Additionally, the system needs to be designed to handle varying water quality, as environmental factors can affect the purity of the condensation. If not properly maintained, there is a risk of system failure, leading to wasted water and operational disruptions. Therefore, ongoing monitoring and maintenance are essential for ensuring both the safety and efficiency of the system.

Sejati & Akbar (2023) when comparing the implementation of an air conditioning condensation utilization system at airports with other studies on water management technologies, several parallels and differences emerge. For instance, the use of IoT (Internet of Things) in irrigation systems has been shown to significantly improve water efficiency by enabling real-time monitoring and automated adjustments based on soil moisture levels (Udanor et al., 2022). This concept can be similarly applied to the air conditioning condensation system, where IoT-enabled sensors could monitor water quality, detect leaks, and ensure optimal collection and filtration processes. Studies on water pump efficiency, such as those focused on reducing energy consumption and maximizing output, also share similarities (Sejati & Akbar, 2023)

Like water pumps, the condensation system requires regular maintenance and monitoring to ensure that the energy and resources invested in the system yield the expected benefits. Lastly, water quality standards, which are crucial in ensuring that water is safe for human use, are an essential consideration in both air conditioning condensation systems and other water management technologies (Ma et al., 2023). Just as in water filtration systems for irrigation or potable water, air conditioning condensation must undergo filtration and treatment to meet safety standards, avoiding contamination risks.

In all these systems, integrating smart technologies, such as IoT and real-time monitoring, can help mitigate risks like contamination and inefficiency, making the systems more reliable and cost-effective over time. Therefore, drawing from successful case studies in irrigation, water pump management, and water quality regulation can inform and enhance the design and operation of air conditioning condensation systems in airports.

Conclusion

This research successfully addresses the issue of condensation water waste from air conditioning systems at airports. Based on the author's calculations, approximately 25,178 liters of condensation water are wasted daily. SUCOFINDO laboratory tests confirmed that this water can be safely reused, particularly for watering plants and fulfilling the 24,300-liter water requirement of the PPKPK Class 9 unit, thus supporting water conservation. To facilitate this reuse, the researcher designed a condensation water reservoir with a capacity twice the daily wastewater volume. The tank is made of UV- and contamination-resistant polyethylene or fiberglass to maintain water quality and prevent rust. Expert validation supports the feasibility of implementing this design at Hang Nadim Batam International Airport to improve operational efficiency and environmental sustainability. To enhance the practical application of this innovation, further research is encouraged. Future efforts should include field trials to assess system performance under real conditions, integration with automated irrigation systems for improved efficiency, and potential implementation at other airports facing similar challenges. This would expand the solution's impact, promoting sustainable water management across the aviation sector.

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