PROPOSED DESIGN OF AN ACTIVE FIRE PROTECTION SYSTEM BASED ON K3 USING ALARM DETECTORS AND SPRINKLERS IN THE WORKING AREA OF AIR SQUADRON 17, HALIM PERDANAKUSUMA AIR BASE

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Abstrak — *This research aims to develop a design proposal for an alarm detector and sprinkler system in the workspace of Air Squadron 17 at Halim Perdanakusuma Air Force Base. Aircraft hangars are work facilities with a high fire risk due to aircraft maintenance activities, the use of technical equipment, the storage of chemicals, and the presence of flammable materials. From an Industrial Engineering perspective, these conditions require the design of a safe, reliable, and sustainable work system through the application of Occupational Safety and Health (OHS) principles. One effective fire risk control measure is the implementation of an active fire protection system in the form of automatic alarm detectors and sprinklers. The research methods used included identifying potential fire hazards, analyzing fire protection system requirements, calculating the number and placement of alarm detectors and sprinklers based on applicable standards, as well as designing pipelines and summarizing material requirements. References used in the design included the NFPA 13 standard and national regulations related to OHS and fire protection. The results of the study indicate that the proposed alarm detector and sprinkler system design is capable of providing optimal fire protection throughout the hangar workspace. This design is expected to improve personnel safety, protect strategic assets, and support the operational continuity of Air Squadron 17. Furthermore, the results of this study can serve as a technical reference in designing fire protection systems in similar work facilities.*

Keywords: *Occupational Safety and Health, Industrial Engineering, Fire Protection Systems, Alarm Detectors, Sprinklers.*

1. INTRODUCTION

Occupational Safety and Health (OHS) from an Industrial Engineering perspective is an integral part of work system design, aimed at creating a safe, efficient, and sustainable work environment. Industrial Engineering views OHS not only as a means of protecting workers but also as a crucial element in optimizing production systems, controlling operational risks, and protecting assets and facilities. With proper OHS implementation, work systems can operate stably without disruption due to accidents or facility damage. Within the Industrial Engineering approach, OHS implemen tation is carried out through a process of hazard identification, risk analysis and assessment, and the design of risk controls integrated into the work system. These risk *controls include technical solutions (engineering controls), work procedure arrangements (administrative controls), and the use of personal protective equipment. Failure to implement OHS principles will directly impact increased downtime, decreased productivity, and increased operational costs due to asset damage and work process disruptions. A hazard in a work system is defined as any source or condition that has the potential to cause harm to people, equipment, materials, or the work environment. In Industrial Engineering, hazards are viewed as risk variables that must be controlled for the system to operate optimally. Hazards can originate from physical, chemical, mechanical, electrical, or human factors and the work environment. If these hazards are not systematically analyzed and controlled, they can develop into system failures or workplace disasters. A disaster in the context of industrial systems is an event that causes significant disruption to system performance, either in the form of loss of life, damage to facilities, or interruption of operational processes. From an Industrial Engineering perspective, disasters are often triggered by weak safety system design, inefficient work procedures, or the lack of adequate risk control systems. Therefore, safety system design is a crucial part of efforts to improve the reliability and safety of work systems. One type of hazard with the greatest systemic impact in industrial environments is fire. Fires occur due to the interaction of heat, fuel, and oxygen, which are generally available in large quantities in technical and industrial facilities. From an Industrial Engineering perspective, fires not only cause physical damage but also impact work process interruptions, increased recovery costs, and reduced operational system reliability. The impacts of fires can include damage to production facilities, loss of high-value assets, injuries or fatalities, and long-term operational disruptions. Therefore, fire hazard control must be systematically designed through the implementation of fire protection systems as part of a safe and efficient work system design. Active fire protection systems, such as automatic sprinklers, are engineered solutions that function as an immediate risk control mechanism in the event of a fire. In this context, aircraft hangars are facilities with highly complex work systems and significant asset value. Aircraft hangars, including those at Squadron 17 Halim Perdana kusuma, play a crucial role in supporting the Indonesian Air Force's flight operations. Activities within the hangar include aircraft maintenance, the use of specialized equipment, the storage of chemicals, and the presence of flammable aircraft components. These conditions make hangars a work system with a high fire risk if not designed with adequate protection systems. From an Industrial Engineering perspective, a fire in an aircraft hangar can be viewed as a system failure that can cause significant losses, both to aircraft assets, supporting equipment, and person nel safety. Therefore, designing active fire protection systems, such as automatic sprinklers, is a crucial part of designing safe, reliable, and efficient work facilities. International standards such as NFPA 13 (Installation of Sprinkler Systems) and national regulations related to OHS and fire protection serve as references in the design of sprinkler systems. In this design, aspects considered include the area and layout of the room, building height, type of work activity, potential heat sources, and the placement of equipment and aircraft. This approach aligns with Industrial Engineering principles, which emphasize analysis- and optimization-based system design. By designing a sprinkler system for an aircraft hangar, it is hoped that an effective and efficient fire protection system will be created as part of the overall work system. This system is expected to prevent, detect, and control fires early, thereby minimizing losses, improving operational reliability, and ensuring personnel safety and protecting the Indonesian Air Force's strategic assets.*

Based on the background described above, the following questions can be formulated: how to design a sprinkler system appropriate to the conditions of the Squa dron 17 Halim Perdanakusuma hangar work space; what standards and regulations are used as references in hangar sprinkler design; and finally, how effective is the sprinkler design in controlling potential fire hazards in the hangar workspace.

2. METHODOLOGY

This research aims to design a sprinkler system as part of the fire protection system in the workspace of Squadron 17, Halim Perdanakusuma. The research object is the primary source of information describing the actual conditions of the workspace and fire protection needs. According to Sugiyono (2013:38), a research object is "an attribute or characteristic value of a person, object, or activity that has certain variables that are applied to be studied and conclusions drawn." Husein Umar (2013:18) adds that a research object describes who and what constitutes the object, as well as where and when the research is conducted. In this context, the research object is the hangar workspace of Squadron 17, Halim Perdanakusuma, with a focus on designing a sprinkler and fire alarm system appropriate to the space's charac teristics and aircraft maintenance activities. The steps in processing anthropometric data are as follows. Data collection was conducted through two primary sources:

- ***Primary Data***
  - *Measurement of the dimensions of the Squadron 17 hangar space*
  - *Collection of workspace plans and layouts*
  - *Interviews with technicians regarding fire-prone areas and protection needs*
- ***Secondary Data***
  - *Technical documents from Squadron 17 Halim Perdanakusuma*
  - *Literature on sprinkler systems and fire protection standards (NFPA, SNI)*
  - *Reference designs for fire protection systems in military facilities*
- ***The steps in designing a sprinkler system are as follows:***
  - *Space Layout Analysis: Determine protection zones based on activities and potential hazards.*
  - *Determining Sprinkler and Alarm Points: Based on spray range and smoke/heat detection standards.*
  - *Water Distribution Simulation: Using CAD software or hydraulic simulation to ensure optimal pressure and coverage.*
  - *Protection Effectiveness Evaluation: Assess whether the design meets fire protection standards and is tech nically feasible.*
  - *Design Documentation: Prepare tech nical drawings, equipment specifi cations, and estimate installation costs.*

3. RESEARCH RESULTS AND DISCUSSION

3.1. Designing and Installing Automatic Fire Detection and Alarm Systems

Systems to minimize the spread of fires are continuously being developed, one of which is the fire alarm system. This alarm will alert us and trigger the fire extinguishing system installed in a building. The specific goal is to prevent the fire from spreading and minimize losses, especially loss of life. In this article, we will discuss fire alarm systems, from their definition to the various types. Automatic fire detection and alarm systems consist of:

- ***Alarm panel;** The alarm panel is the control center of the fire detection system. All signals from heat, smoke, and manual call points are received and processed by this panel. The alarm panel also controls the activation of audible and light alarms and can be connected to the sprinkler system. he* *alarm panel is usually placed in a control room or security room that is easily accessible to officers, near the main entrance to the hangar or work area.*

Figure 1 Alarm Panel

- ***Heat and smoke detectors;*** *Heat detectors detect significant tempera ture increases, while smoke detectors detect smoke particles in the air. Both operate automatically to provide an early warning before a fire spreads. Installed on the ceiling of the room with a spacing according to NFPA 72 standards, especially in high-risk areas such as server rooms, laboratories, machine maintenance rooms, and main hangar areas.*

Figure 2. Heat and Smoke Detector

- ***Manual call points;*** *A manual call point is a device that allows personnel to manually activate the fire alarm by pressing a glass button when they see signs of fire. They are installed on walls near exits, corridors, and evacuation routes at a height of approximately 1.2–1.5 meters above the floor for easy access.*

Figure 3. Manual Call Point

- ***Alarm signal (alarm bell/buzzer/ light).*** *An alarm signal in the form of a bell, buzzer, or indicator light provides an audible and visual warning to all building occupants in the event of a fire.*

Figure 4 Alarm Signal (Alarm Bell/Buzzer/Lamp)

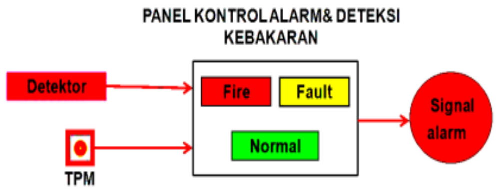

Figure 5 Automatic Fire Detection and Alarm System

- ***Fire Alarm System;*** *Figure 6 illustra tes the automatic fire alarm and detection system. It works by sending a signal to the panel when a smoke or heat detector signals smoke or heat that exceeds the standard. Similarly, if a person or officer sees a fire, they can immediately break the glass at the manual call point. The transmitted signal is then received by the electrical panel, which then triggers the alarm. The alarm system is proposed to be installed on the north wall of the building, 1.5 meters above the floor, as shown in Figure 6*

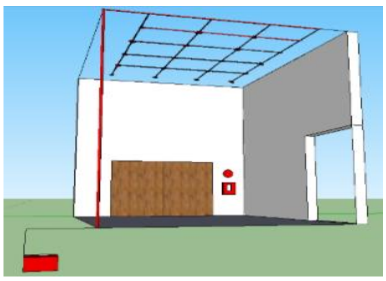

Figure 6 Installation of Fire Alarm System

3.2 Fire Detector Design

Installing heat and smoke detectors is an early fire detection system. When signs of *a fire occur in a building, such as the presence of smoke or the first signs of a flame, these devices can signal the location of the incident. There are several types of detector systems, including:*

- ***Heat Detectors.** Due to their simplicity, these detectors are slow to respond to fires. These devices require sufficient heat to generate an alarm before sending an alarm. By the time the alarm is sent, the fire is often difficult to control due to the lengthy heating process.*
- ***The installation requirements for heat detectors are as follows**:*
  - *1). They must be installed 15 mm to 100 mm below the building's ceiling.*
  - *2). No more than 40 of these systems may be installed in a group.*
  - *3). For every 46 m2 of floor area and a ceiling height of 3.00 meters.*
  - *4). The distance between detectors must be no more than 7.00 meters for active spaces and no more than 10.00 meters for circulation spaces.*
  - *5). The detector must be at least 30 cm from the wall.*
  - *6). At different heights, one detector must be installed for every 92 m2 of floor area.*
  - *7). At the top of the roof curve of a hidden space, one detector must be installed for each longitudinal distance.*
  - ***Smoke Detector**. This device auto matically alerts everyone if smoke is present in an area by sounding an alarm. This device is specifically for indoor use. When installing smoke detectors, the following requirre ments must be met:*
    - *For every 92 m2 of floor area.*
    - *2). The maximum distance between detectors is 12.00 meters in active spaces and 18.00 meters for circulation spaces.*
    - *3). The minimum distance bet ween detectors and walls is 6.00 meters for active spaces and 12.00 meters for circulation spaces.*
    - *4). Each system group is limited to a maximum of 20 detectors to protect a 2,000 m2 room.*

In this design, we use detectors capable of detecting both heat and smoke. They are placed on the north, east, and south walls at a height of 5 meters from the floor, with each detector spaced 7 meters apart. The design and placement of the heat and smoke detectors can be seen in Figure 7.

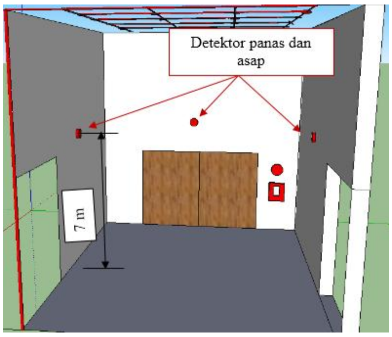

Figure 7 Proposed Placement of Heat and Smoke Detectors

3.3. Sprinkler System Design

Sprinkler System Design for Floor 1A. The design was conducted using a technical approach, including an analysis of sprinkler point requirements, 1/2-inch diameter branch pipe lines, and necessary fittings (elbows, tees, and watermurs/ couplings).

- ***Room Identification**; The rooms analyzed included: Cashier, Staff, TUT, Avionics, Kencana Terrace, Urdal, Lambangja, Health, and VIP Room. Each room has different characteristics and functions, so sprinkler distribution was carried out proportionally.*
- ***Sprinkler Spacing Standard**; The standard sprinkler installation distance*

used was 360 cm × 360 cm (light hazard category), so each sprinkler can protect an area of 129,600 cm².

- ***Number of Sprinklers****; Based on the total area, the number of sprinklers designed is 36, distributed per room: Kashar (4), Staff (3), TUT (5), Avionics (3), Kencana Terrace (7), Urdal (3), Lambangja (4), Health (4), and VIP Room (3).*
- ***Pipeline Analysis****; A 1/2-inch diameter branch pipe is drawn along the red line on the floor plan, with a total straight segment length of 6,500 cm. Each sprinkler is connected via a 30 cm long vertical drop pipe, resulting in a total drop length of 1,080 cm. Thus, the total length of the branch pipe is 7,580 cm.*
- ***Fitting Calculation****; Elbow: The pipe line experiences 11 90° bends in total, requiring 11 elbows. Tee: Each sprinkler is connected via a tee, requiring a total of 36 tees. Watermur/ Coupling: The total pipe length of 7,580 cm is equivalent to 13 pipe rods (6 m per rod). The connections between rods require 12 watermurs/couplings.*
- ***Analysis per Room****;*
  - *Cashier Room; Four sprinklers are allocated with a branch line of 842 cm (722 cm horizontal + 120 cm drop). The pipe line has one 90° bend, requiring one elbow. The connections to the sprinklers use four tees, with one watermur for the connection between the rods. This configuration ensures even water distribution throughout the Cashier Room.*
  - *Staff Room; The staff room is smaller, so three sprinklers suffice. The pipe line is 632 cm long (542 cm horizontal + 90 cm drop), relatively straight with no bends, so it does not require additional elbows. The connections to the sprinklers use three tees, with one watermur for the connection between the rods. This design is efficient and simple.*
  - *Tool Utility Tools (TUT) Room The TUT room is allocated five sprinklers with a branch line length of 1,053 cm (903 cm horizontal + 150 cm drop). The pipeline has two 90° bends, requiring two elbows. The sprinkler connections use five tees, with two watermurs for connections between the rods. This configuration accommodates more complex room shapes.*
  - *Avionics Room; The Avionics Room has critical technical functions, so three sprinklers are installed. The pipeline is 632 cm long (542 cm horizontal + 90 cm drop), with one 90° bend, requiring one elbow. The sprinkler connections use three tees, with one watermur. This protection is crucial for sensitive avionics equipment.*
  - *Kencana Terrace Room; The Kencana Terrace Room is the largest area, so seven sprinklers are allocated. The pipe line is 1,474 cm long (1,264 cm horizontal + 210 cm drop), with two 90° bends, requiring two elbows. The sprinkler connection uses seven tees with three water pipes. This configuration ensures complete protection of the terrace area.*
  - *Internal Affairs Room (Urdal); The Urdal Room is allocated three sprinklers with a branch line of 632 cm (542 cm horizontal + 90 cm drop). The pipe line has one 90° bend, requiring one elbow. The sprinkler connection uses three tees with one water pipe. This design is simple yet effective.*
  - *Symbol Room; The Symbol Room is allocated four sprinklers with a branch line of 842 cm (722 cm horizontal + 120 cm drop). The pipe line is relatively long with two 90° bends, requiring two elbows. The*

sprinkler connection uses four tees with two water pipes. This configu ration ensures optimal room safety.

- *Medical Room; The medical room requires special protection, so it is allocated four sprinklers. The pipe line is 842 cm long (722 cm horizontal + 120 cm drop), with one 90° bend, requiring one elbow. The sprinkler connections use four tees with one watermur. This design ensures the safety of patients and medical equipment.*
- *VIP Room; The VIP room is allocated three sprinklers with a branch line 632 cm long (542 cm horizontal + 90 cm drop). The pipe line has one 90° bend, requiring one elbow. The sprinkler connections use three tees, with 0–1 watermur depending on the length of the line. This configuration provides maximum protection without compromising the comfort of the VIP room.*

Ruangan	Luas(cm)	Sprinkler	Panjang Pipa (cm)	Elbow	Tee	Watermur
Kashar	600 x 700	4	842	1	4	1
Staf	350 x 700	3	632	0	3	1
TUT	270 x 700	5	1053	2	5	2
Avionik	250 x 700	3	632	1	3	1
Kencana Terrace	600 x 700	7	1474	2	7	3
Urdal	950 x 700	3	632	1	3	1
Lambangja	270 x 700	4	842	2	4	2
Kesehatan	400 x 700	4	842	1	4	1
VIP Room	550 x700	3	632	1	3	1
Total		36	7581	11	36	13

Table 1 Summary of Combined Materials for Floor

The design of this sprinkler system resulted in a configuration that meets fire protection standards, with a total of 36 sprinkler points, 7,580 cm of 1/2" branch pipe, and fitting requirements consisting of 11 elbows, 36 tees, and 12–13 watermurs/ couplings. A room-by-room analysis demonstrated a proportional distribution of materials according to the room's size and function. The results of this study can be used as a basis for material procurement, cost estimation, and evaluation of the effective ness of the fire protection system. Further more, the room-by-room breakdown provides a more detailed overview of installation requirements, facilitating future implementation and maintenance.

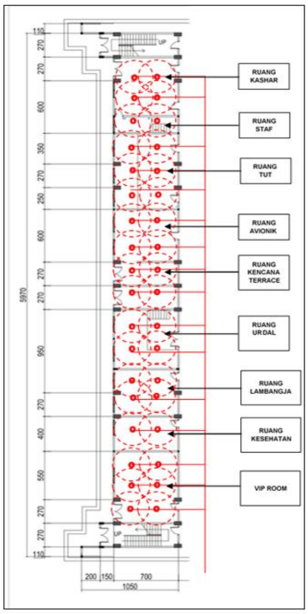

Figure 8: Sprinkler Point Design for Floor 1A

3.4 Sprinkler System Design for Floor 2

The design was conducted using a technical approach that included an analysis of sprinkler point requirements, 1/2-inch diameter branch pipe lines, and the necessary fittings (elbows, tees, and watermurs/couplings).

- ***Kitchen;** Five sprinklers were allocated with a branch line length of 1,053 cm (903 cm horizontal + 150 cm drop). The pipe line has two 90° bends, requiring two elbows. The sprinkler connections use five tees, with two watermurs for connections between the rods. This design is important because the kitchen is a high-risk fire area.*
- ***Crew Room**; Four sprinklers were allocated with a branch line length of 842 cm (722 cm horizontal + 120 cm drop). The pipe line has one 90° bend, requiring one elbow. The sprinkler connections use four tees, with one watermur. This configuration ensures protection for the crew rest area.*

- ***Danflight Room****; The Danflight Room is allocated four sprinklers with a branch line length of 842 cm. The pipeline has two 90° bends, requiring two elbows. The sprinklers are connected using four tees with two water pipes. This design supports the safety of the flight command room.*
- ***Classroom****; The Classroom is allocated six sprinklers with a branch line length of 1,264 cm (1,054 cm horizontal + 210 cm drop). The pipeline has two 90° bends, requiring two elbows. The sprinklers are connected using six tees with two water pipes. This configuration ensures full protection for the learning space.*
- ***Set Room****; The Set Room is allocated three sprinklers with a branch line length of 632 cm (542 cm horizontal + 90 cm drop). The pipeline has one 90° bend, requiring one elbow. The sprinklers are connected using three tees with one water pipe.*
- ***Operations Room****; The Operations Room is allocated four sprinklers with a branch line 842 cm long. The pipeline has one 90° bend, requiring one elbow. The sprinkler connection uses four tees and one water pipe.*
- ***Operations Room****; The Operations Room is allocated five sprinklers with a branch line 1,053 cm long. The pipeline has two 90° bends, requiring two elbows. The sprinkler connection uses five tees and two water pipes.*
- ***Command Room****; The VIP Room is allocated five sprinklers with a branch line 1,053 cm long. The pipeline has two 90° bends, requiring two elbows. The sprinkler connection uses five tees and two water pipes.*

Ruangan	Luas(cm)	Sprinkler	Panjang Pipa (cm)	Elbow	Tee	Watermur
Dapur	450 x 500	5	1053	2	5	2
Crew Room	550 x 500	4	842	1	4	1
Danflight	550 x 500	4	842	2	4	2
Kelas	1200 x 500	6	1264	2	6	2
Set	600 x 500	3	632	1	3	1
Kasiops	600 x 500	4	842	1	4	1
Operasi	550 x 500	5	1053	2	5	2
Komandan	820 x 500	5	1053	2	5	2
Total		36	7581	13	36	13

Table 2 Summary of Combined Materials for Floor 2

The sprinkler system design for the operational room complex resulted in a configuration with a total of 36 sprinkler points, 7,580 cm of 1/2" branch pipe, and fitting requirements consisting of 13 elbows, 36 tees, and 13 watermurs/ couplings. A room-by-room analysis demonstrated a proportional distribution of materials according to each room's function and fire risk. The results of this study can be used as a basis for material procurement, cost estimation, and evaluation of the effectiveness of the fire protection system. The room-by-room breakdown provides a detailed overview of installation requirements, facilitating future implementation and maintenance.

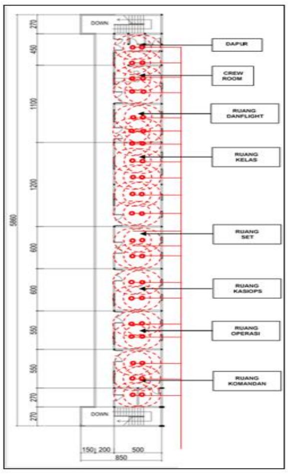

Figure 9: Sprinkler Point Design on Floor 2

3.5 Sprinkler System Design on Floor 1B

This research focuses on the design of a sprinkler system through a technical approach, including an analysis of sprinkler point requirements, 1/2-inch diameter branch pipe lines, and supporting fitting components. The main objective of the research was to produce a design that is efficient in material use and can be used as *a basis for calculating the cost budget (RAB). Based on the technical plan and material calculations, the following is a breakdown of the distribution in each zone:*

- ***Air Mechanic Room** (JMU); The JMU room is allocated six sprinkler points divided into two parallel rows. The branch pipe line is approximately nine meters long and consists of horizontal pipes and drops to the sprinklers. This configuration requires two elbows for bends, six tees for connections to each sprinkler, and two water nuts for connections between the rods.*
- ***Tools Room**; The Tools Room is also allocated six sprinkler points in a two-parallel row configuration. The branch pipe line is the same length as the JMU room, with two elbows, six tees, and two water nuts. This protection is important because the room stores work equipment that must be protected from fire risks.*
- ***Petroleum Oil and Lubricant (P.O.L.) Warehouse**; The P.O.L. warehouse is allocated three sprinkler points over a two-point-seven-meter area. The branch pipeline is shorter with one ninety-degree turn, requiring one elbow, three tees, and one watermur.*
- ***Airframe Room**; The Airframe Room, as one of the largest areas, is allocated nine sprinkler points with a twelve-meter branch line. Sprinkler distribution is arranged in a three-by-three grid pattern for comprehensive coverage. The pipeline requires two elbows, nine tees, and three watermurs. Uniform protection across the entire work area is a priority because intensive technical activities take place here.*
- ***Engine Room**; The Engine Room is allocated six sprinkler points with a total length of approximately five-point-four meters, divided into two bulkheads. The branch pipeline uses two parallel rows with two elbows, six tees, and two watermurs. The engine, as a local heat source, requires stable and segmented protection.*
- ***Spare Parts Room**; The Spare Parts Room is allocated nine sprinkler points with a twelve-meter branch line. Sprinkler distribution is designed in a three-by-three grid pattern to protect racks and storage aisles. The piping requires two elbows, nine tees, and three watermurs. Protecting high-value inventory is the primary focus.*
- ***Kencana Hall**; As a public space, Kencana Hall is allocated nine sprinkler points with twelve-meter branch lines. Sprinkler distribution is designed in a three-by-three grid pattern for comprehensive coverage. The piping requires two elbows, nine tees, and three watermurs. Comprehensive protection in this gathering space is crucial for both safety and the aesthetics of the system.*

The following is a complete material requirements table based on the design results:

Ruangan	Luas(cm)	Sprinkler	Panjang Pipa (cm)	Elbow	Tee	Watermur
Ruang JMU	540 x 900	6	1262	2	6	2
Ruang Tools	600 x 900	6	1322	1	6	2
Ruang Gudang P.O.L.	270 x 900	3	592	1	3	1
Ruang Airframe	850 x 900	9	1872	2	9	3
Ruang Engine	270 x 900	6	1262	2	6	2
Ruang Sparepart	950 x 900	9	2072	2	9	3
Ruang Kencana Hall	270 x 900	9	2072	2	9	3
Ruang Bawah (Lainnya)	270 x 900	6	1262	2	6	2
Total		54	11716	14	54	18

Table 3 Material Summary 1B

The design of this sprinkler system resulted in a configuration that meets fire protection standards, with a total of 54 sprinkler points. The total length of branch pipes required was 11,716 cm, supported by fittings consisting of 14 elbows, 54 tees, and 18 watermurs for connections between pipe trunks. This analysis provided a detailed overview that facili *tated the material procurement process and field installation implemen tation.*

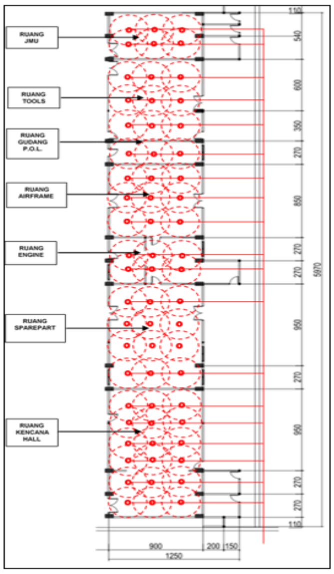

Figure 10 Design of Sprinkler Points on the 1st Floor.

3.6 Main Distribution Route

The design of the sprinkler system in the 17th Air Squadron hangar was carried out using a comprehensive technical approach, encompassing room identification, sprinkler point requirement analysis, pipe distribution routes, and fitting calculations. Each floor and additional area was analyzed in detail to ensure that fire protection could reach all spaces proportionally according to their function and size. On the first floor, protection focused on administrative and operational spaces such as the Cashier, Staff, TUT, Avionics, Kencana Terrace, Urdal, Lambangja, Health, and VIP Room. Sprinkler distribution was arranged to ensure full coverage for each room, with a total of 36 sprinkler points. On the second floor, protection was extended to operational support spaces such as the Kitchen, Crew Room, Flight Commander, Classroom, Set, Operations Chief, Operations, and Commander. Similar to the first floor, 36 sprinklers were installed, with pipe routes and fittings adapted to the more varied room shapes.

Meanwhile, additional areas, including the JMU (Aircraft Maintenance Unit), Tools Room, P.O.L. Warehouse, Airframe, Engine, Spare Parts Room, and Kencana Hall, have more complex technical charac teristics. Because these spaces are directly related to aircraft maintenance and the storage of critical materials, the number of sprinklers was increased to 48. The length of piping and fitting requirements are also greater than those on the first and second floors, making the protection system in these areas a top priority. Overall, the recapitulation results show that the 17th Air Squadron hangar sprinkler system requires:

- *120 sprinkler points to protect the entire space.*
- *25,614 cm of 1/2-inch diameter branch pipe as the main distribution line.*
- *36 elbows, 120 tees, and 42 watermurs/ couplings to ensure safe and efficient pipe connections.*

This configuration not only meets light hazard fire protection standards but also provides a clear picture of material requirements and cost estimates. With a systematic design, this sprinkler system is expected to provide maximum protection for personnel, equipment, and strategic assets of Air Squadron 17.

- ***Water Source** (Water Tank):*
  - *The water tank serves as the main reservoir.*
  - *Water is channeled to the pump room through a standard-diameter main pipe (≥ 2 inches for supply capacity).*
- ***Pump Room:***
  - *A high-pressure pump is installed to ensure the flow rate and pressure meet sprinkler standards.*
  - *From the pump room, the main pipe is divided into three distribution lines to three buildings (Building A, Building B, Building C).*
- ***Distribution to Buildings:***
  - *Each building receives its supply through a main branch pipe, which is then lowered into 1/2-inch diameter branch pipes according to the sprinkler requirements per room.*

- *The pipe route follows the red line on the floor plan, with a total length of 7,580 cm, including the vertical drop pipe.*
- *Length 7,580 cm, including the vertical drop pipe.*

Lantai / Area	Sprinkler	Panjang Pipa (cm)	Elbow	Tee	Watermur
Lantai 1 A	36	7581	11	36	13
Lantai 2	36	7581	13	36	13
Lantai 1B	54	10454	12	48	16
TOTAL GABUNGAN	124	25614	36	120	42

Table 4 Overall Combined Recapitulation

3.7. Designing Water Requirements, Pumps, and Storage Tanks

The sprinkler fire protection system is a vital component in the design of the 17th Air Squadron hangar. With a large number of sprinklers, water distribution must be carefully designed to ensure the safety of personnel, equipment, and strategic assets. Therefore, calculating water requirements, pump capacity, and storage tank dimen sions are the primary basis for designing this system. Water Require ments;The number of sprinklers installed is 124, with a flow rate of 35 liters per second each. If all sprinklers operate simulta neously, the total required flow rate is:Q total = 120 x 35 = 4,200 liters/second For a 30-minute operation duration (1,800 seconds), the water requirement is: V30 = 4,200 x 1,800 = 7,560,000 liters = 7,560 m3. Therefore, the sprinkler system requires a water supply of 7,560 m³ to ensure full operation for 30 minutes. Pump Capacity; The pump must be capable of supplying a total flow rate of 4,200 liters/second, or equivalent to:
4,200 x 3,600 = 15,120,000 liters/hour = 15,120 m3/hour.The recommended pump system is:

- *Two main pumps with a capacity of approximately 7,560 m³/hour each.*
- *One backup pump with the same capacity to ensure system reliability.*

The generator set uses a 500 kVA generator for a pump with a capacity of 7,560 m³/hour. This configuration ensures a continuous water supply even if one of the pumps fails.

Storage Tank Dimensions; To accom modate the 7,560 m³ volume, the dimensions of the storage tank are adjusted to suit the site conditions. If the height of the tank is set at 3 meters, the required base area is:
L × W = 7.5603 = 2,520 m²
Some alternative tank sizes:
a) 42 m × 60 m × 3 m = 7,560 m³
b) 36 m × 70 m × 3 m = 7,560 m³
c) 30 m × 84 m × 3 m = 7,560 m³
If the height of the tank is increased to 6 meters, the base area can be reduced to 1,260 m², for example, with dimensions of 30 m × 42 m × 6 m.

Conclusion; The design of water requirements, pumps, and reservoirs shows that:

- *30-minute water requirement: 7,560 m³*
- *Total pump capacity: 15,120 m³/hour (2 main pumps + 1 backup)*
- *Reservoir: minimum 7,560 m³, with dimensions varying according to the selected height (e.g., 42 × 60 × 3 m or 30 × 42 × 6 m).*

This design provides a clear technical description and can be used as a basis for material procurement, cost estimation, and evaluation of the effectiveness of the fire protection system in the Air Squadron 17 hangar. Furthermore, the design of the Sprinkler Points, Water Tanks, and Pumps can be seen in Figure 11.

Figure 11: Sprinkler, Pump, and Water Tank Design

The sprinkler system configuration not only meets light hazard fire protection standards but also provides a clear picture of material requirements and cost estimates. The system consists of three main components: a water source (reservoir tank), a pump room, and distribution lines to the buildings. The water tank serves as the main reservoir, with water flowing to the pump room through a main pipe with a diameter of ≥ 2 inches. A high-pressure pump is installed in the pump room to ensure the flow rate and pressure meet sprinkler standards. From the pump room, the main pipe is divided into three distribution lines to Building A, Building B, and Building C. Each building receives its supply through the main branch pipe, which is then lowered into ½-inch branch pipes according to the sprinkler requirements per room. The pipe route follows the red lines on the floor plan, with a total length of 25,614 cm, including the vertical drop pipes. The recapitulation of material requirements is shown in Table 4.4, with a total of 124 sprinklers, a pipe length of 25,614 cm, 36 elbows, 120 tees, and 42 watermurs. The calculation of water requirements shows that the numberof sprinklers installed is 124, with a discharge of 35 liters/ second each. If all sprinklers operate simulta neously, the total discharge required is 4,200 liters/second. For an operating duration of 30 minutes (1,800 seconds), the water requirement reaches 7,560 m³. The required pump capacity is 15,120 m³/hour, so it is recommended to use two main pumps with a capacity of ± 7,560 m³/hour each, plus one backup pump with the same capacity to ensure system reliability. To support pump operations, a 500kVA generator set is used. The dimensions of the storage tank are adjusted to suit the site conditions, for example, 42 m × 60 m × 3 m or 30 m × 42 m × 6 m, with a minimum volume of 7,560 m³. The sprinkler layout of the aircraft hangar shows the pipe distribution routes following the red lines on floors 1A, 1B, and 2. Sprinkler points are evenly spaced in the server room, headroom, meeting room, admin room, laboratory, and the main area of the hangar that houses the aircraft. This configuration ensures that every high-risk area receives direct protection. With a systematic design, this sprinkler system is expected to provide maximum protection for personnel, equipment, and strategic assets of Air Squadron 17. The integration of the HIRADC concept and hydraulic calculations ensures that this design not only meets fire protection standards but also provides a clear technical basis for material procure ment, cost estimation, and evaluation of the effectiveness of the fire protection system in the aircraft hangar.

4.CONCLUSION AND RECOMMENDATIONS

Based on the analysis and discussion in Chapter IV regarding the design of the fire protection system in the Halim Perdana kusuma Air Squadron 17 Hangar, the follo wing conclusions can be drawn:

- *The designed sprinkler system has been adapted to the conditions of the hangar workspace, taking into account the area, function, and risk level of each room. The sprinkler points are distributed proportionally to protect the entire area, with a total of 120 sprinkler points connected via ½-inch diameter branch pipes.*
- *The sprinkler design adheres to applicable standards and regulations,*

namely NFPA 13 (National Fire Protection Association) and SNI 03-3989-2000 concerning procedures for designing automatic sprinkler systems. These standards serve as guidelines for determining installation spacing, discharge capacity, number of sprin klers per floor area, and technical requirements for piping and fittings.

- *The sprinkler design has proven to be highly effective in controlling potential fire hazards. This is demonstrated by its even distribution, adequate pump capacity (15,120 m³/hour), and a minimum reservoir capacity of 7,560 m³ for 30 minutes of full operation. This system is capable of providing maximum protection for Air Squadron 17's personnel, equipment, and strategic assets.*

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