



Design, Build and Test the Performance of an Eco-Friendly Urban Garbage Burning Machine

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Abstract

The problem of urban waste management continues to be a global challenge, especially in areas with rapid population growth such as Kupang City. Inadequate waste management infrastructure and conventional disposal methods, such as open burning and landfills in landfills, increase the risk of environmental pollution and public health. Therefore, this study aims to design, build, and test the performance of environmentally friendly urban waste incinerators as a more effective and sustainable alternative solution. The research methods used include surveying and observing waste management conditions in Kupang City, designing and manufacturing waste incinerators, and testing their performance in various operational parameters. The evaluation includes combustion efficiency, exhaust emissions, operational stability, and the environmental impact of using this engine. The results of the study show that the developed waste incinerator is able to reduce the volume of waste by up to 95% with exhaust gas emissions remaining within the safe threshold. The closed combustion system applied allows for a cleaner and more efficient combustion process than conventional methods. In addition, the modular and flexible design allows for implementation at various scales, whether in residential, commercial, or small-scale waste management facilities. With the right policy and regulatory support, this machine has the potential to become an innovative solution for more sustainable waste management in cities.



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INTRODUCTION

Modern cities around the world are faced with serious challenges in waste management. Rapid population growth and urbanization have led to a drastic increase in the volume of waste generated, while waste management infrastructure is often unable to cope with the burden effectively (Sayrani & Tamunu, 2020). This problem is exacerbated by the use of environmentally unfriendly waste disposal methods, such as open burning, which produce toxic emissions and damage the environment as well as human health (Ayen et al., 2016).

Kupang City, as one of the urban centers in Indonesia, faces serious challenges related to waste management. Rapid population growth and high urbanization have led to an increase in the

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volume of waste generated every day. Unfortunately, the waste management infrastructure in Kupang City has not been able to keep up with this growth effectively (Arena, 2012).

One of the main problems faced by Kupang City is the lack of an orderly and even waste collection system throughout the city area. This leads to the accumulation of garbage in inappropriate places, such as roadsides, rivers, and vacant lots, which disrupts the beauty of the city and increases the risk of environmental pollution (Yasir, 2021). In addition, the approach to waste management that still relies on open burning and landfill in landfills (landfills) that are not properly managed is also a serious problem. This practice not only creates air pollution that is harmful to public health, but also increases the risk of environmental damage and soil and water pollution (Ratnani, 2008).

The geographical condition of Kupang City which is located in a coastal area also adds complexity in waste management, with the potential for marine pollution that can threaten the sustainability of marine ecosystems. Therefore, handling the waste problem in Kupang City requires a holistic approach, including improving waste management infrastructure, increasing public awareness about the importance of responsible waste management practices, and applying technology and innovation in more environmentally friendly waste management.

Previous research has identified a variety of problems caused by uncontrolled urban waste incineration. Some of the main problems that often occur include harmful gas emissions that can pollute the air and interfere with human health, greenhouse gas production that contributes to global warming, and negative impacts on soil and water quality due to waste from incineration. A study conducted by Rahmawati and Syamsu (2021) highlights that burning garbage produces toxic gas emissions such as carbon monoxide and sulfur dioxide that can damage human health and ecosystems (Rahmawati & Syamsu, 2021). Meanwhile, research by Zahra (2019) shows that the process of burning waste also produces greenhouse gases such as carbon dioxide and methane, which accelerate climate change (Zahra, 2019). By understanding these negative impacts, the development of technology-based solutions that can reduce harmful emissions and improve combustion efficiency is very important.

This research focuses on the design and development of environmentally friendly waste incinerators as a solution to waste management problems in Kupang City. The machine is designed to address the various obstacles that arise from conventional waste incineration methods, especially in terms of exhaust emission control, energy efficiency, and environmental impact reduction. This research aims to analyze the actual condition of waste management in Kupang City, including the available infrastructure, waste collection and processing methods, and the main challenges faced. In addition, this study will also identify the characteristics of the urban waste produced, including its composition, volume, and physical and chemical properties. Furthermore, this study will evaluate the requirements and standards that must be met by waste incinerators in order to be considered environmentally friendly, especially related to gas emissions, energy efficiency, and waste treatment from incineration. By understanding these aspects, this research will design and develop a waste incinerator engine that suits the specific needs and conditions of Kupang City, considering the operational scale, availability of alternative fuels, and the most appropriate technology to be applied.

Through this research, it is hoped that innovative solutions can be found that can increase efficiency and sustainability in waste management in Kupang City. The designed waste incinerator is expected to be able to be a more environmentally friendly alternative to conventional methods, so that it can reduce negative impacts on public health and the surrounding environment.

METHOD

The method used in this study is an action method that begins with a survey and observation of the temporary waste disposal site, technological planning, making design drawings and making

products or machines that will be used to burn waste, and ends with functional tests and machine performance tests. The outputs of this research consist of: (1). An environmentally friendly urban waste incinerator, (2). Publications in reputable National or International journals, as well as 2 (two) titles of final projects/theses for students of the Production and Maintenance Machinery Engineering Study Program.

Research Stages

The steps or stages of this research can be explained as follows:

1. Survey and Observation;

Surveys and observations were carried out with the aim of observing and discussing and interviewing village officials and communities in coastal areas and residents who live in places where piles of garbage are often found to study the problems they face.

2. Problem Identification;

Problem identification is carried out with the aim of determining and defining problems obtained during surveys and observations. Some of the problems that the researchers have successfully identified include: the lack of an orderly and even waste collection system throughout the city. This causes the accumulation of waste in inappropriate places, such as roadsides, rivers, and vacant land, which disturbs the beauty of the city and increases the risk of environmental pollution, lack of public awareness to dispose of waste in designated landfills, relatively far away waste disposal sites, In addition, the approach in waste management that still relies on open burning and landfill in landfills (Final Disposal Sites) that is not managed properly is also a serious problem. This practice not only creates air pollution that is harmful to public health, but also increases the risk of environmental damage and soil and water pollution.

3. Literature Review;

The literature review was carried out with the aim of studying various sources and references related to previously identified problems, especially research published in scientific journals that discuss urban waste management issues, as well as various previously existing waste incineration processing technologies.

4. Planning tools and image creation

Planning and design of tools is carried out by considering various aspects of tightening such as functional aspects, construction aspects, ease of operation and maintenance of tools, and the availability of materials and tools at the local level. After the planning and design of this tool is completed, it is continued by making drawings of the design of the tool and working drawings.

5. Procurement of materials and tools

The procurement of materials and tools is carried out after the design drawings and work drawings are completed. The materials selected and provided in this process must be materials that are easy to find and available at the local level

6. Component Manufacturing and Tool Construction

The process of making components is carried out at the Mechanical Technology Workshop of the Department of Mechanical Engineering, Kupang State Polytechnic with adequate technology and equipment support

7. Assembly

After all the components are completed, the next stage is the assembly stage

8. Functional Testing Tool

Tool Functional Test: Functional tests are carried out with the aim of finding out whether the waste incinerator has worked according to the plan and criteria that have been set or not. Functional testing must pay attention to whether each engine component is individual and also

pay attention to whether the entire system has worked according to its function or not. If it is found that there are components or systems that do not work as planned, it is necessary to carry out modifications or re-planning

9. Tool Performance Trials

After the engine has been confirmed to be working properly through functional tests, it is continued with engine performance tests. This performance test is carried out to find out the performance of the engine such as combustion time, combustion emission quality, engine capacity, combustion efficiency, etc.

10. Reporting

Reporting consisting of research report and financial statements. Both types of reports are carried out as administrative and financial accountability and the DIPA of the Kupang State Polytechnic in 2024

11. Seminars and Publications

The seminar and publication stage is one of the important targets of the output of this research. The seminar will be held during the 6th International Conference on Applied Science and Technology (iCAST)202.

RESULT AND DISCUSSION

This research aims to design, build, and test the performance of environmentally friendly urban waste incinerators. Based on these objectives, some of the main outputs and results of this study are as follows:

Eco-Friendly Urban Garbage Burning Machine Design

The prototype of an environmentally friendly urban waste incinerator machine developed in this study is designed with combustion efficiency, emission control, and environmental sustainability in mind. A prototype image of this garbage incinerator can be seen in images (1, and 2). Some of the key features of this prototype engine include:

1. Efficient Combustion System

This technology also optimizes the use of energy generated from waste incineration, by generating heat that can be reused for the process of heating the waste to be burned. This reduces the need for additional fuel and makes the engine more energy efficient.

2. Eco-Friendly and Sustainable Design

The machine is designed with materials that are not only durable and strong, but also environmentally friendly. The construction materials used include stainless steel and composite materials that can withstand high temperatures without corrosion, thereby extending the life of the machine and reducing the environmental impact of machine production waste.

The manufacturing process of this machine also pays attention to the principles of the circular economy, using components that can be recycled or reused in the future. This helps reduce the carbon footprint of the manufacturing process and the use of the machine.

3. Waste Processing Capacity and Flexibility

This prototype machine has a varied waste processing capacity, according to the type and amount of waste to be burned. This machine can process household waste, organic waste, and inorganic waste, with adjustable settings for different types of waste.

This machine is designed to be used at various scales, ranging from the household level, residential facilities, to the city scale. This allows the implementation of machines in different locations with different waste needs.

4. Safety and Ease of Operation

- 9) Copper Hose
- 10) Machine Frame
- 11) Combustion Room Cover
- 12) Hoper Enters Garbage
- 13) Burning Ash Containment Box
- 14) Combustion Room Cover Plate
- 15) Chimney
- 16) Flue Pipe

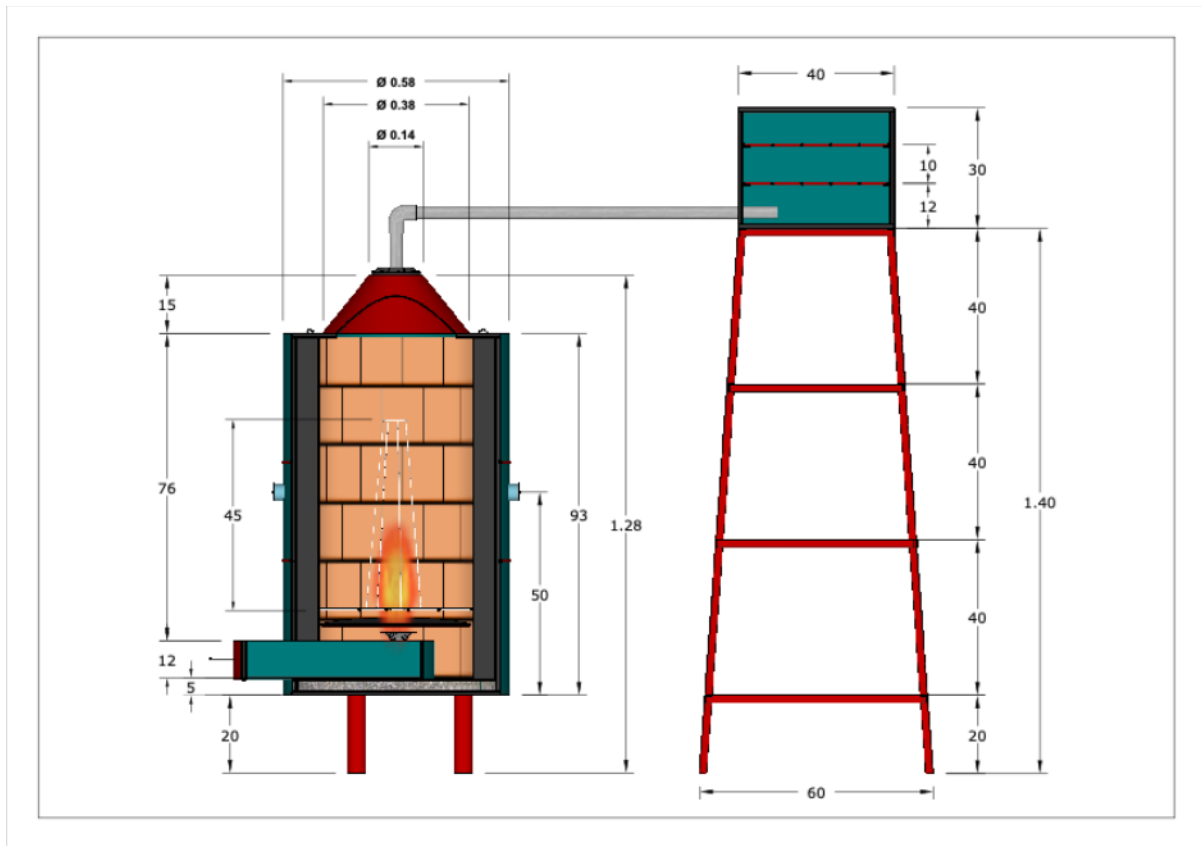


Figure 2. Cross-section Design of Garbage Burning Machine

Garbage Burning Machine Manufacturing Process

Waste management in urban areas is a major challenge faced by many cities around the world. One effective solution is to utilize an environmentally friendly waste incinerator. This machine is designed to reduce the volume of waste through an efficient combustion process, so as to reduce the negative impact on the environment. In this report, it will be explained in detail about the process of making an environmentally friendly waste incinerator and its components.

1. Components of a Garbage Burning Machine

An eco-friendly waste incinerator consists of several main components that work together to run the combustion process properly. Here is a brief description of each component:

- a. Kerosene Cylinder Wind Pump; This component functions to put air into the kerosene fuel reservoir tube so that the fuel from the tube is flowed into the combustion chamber with enough pressure to change the natural oil liquid into mist so that it is more flammable and the combustion process runs optimally. Where was this wind pump purchased

- b. Copper Hose: This hose is used to flow air and fuel from the wind pump to the combustion chamber. High quality copper guarantees durability and airflow efficiency; This copper hose was purchased
 - c. Machine Frame: The machine frame serves as the main structure that supports all other components. This frame should be made of strong, heat-resistant materials. The frame of this machine is made
 - d. Combustion Chamber Cover: This component closes the combustion chamber to maintain a high temperature during the combustion process and prevent smoke from escaping prematurely.
 - e. Garbage Entry Hoper: This hoper is a place to put garbage into the machine. The design should make it easy for users to safely put in the garbage.
 - f. Incinerated Ash Collection Box: After the combustion process is complete, the incinerated ash will be accommodated in this box for easy cleaning.
 - g. Combustion Chamber Cover Plate: This plate serves to close the combustion chamber so that no unburned material comes out of the engine.
 - h. Chimney: This chimney is used to remove combustion smoke into the air. The design must pay attention to the smoke filtration aspect so as not to pollute the environment.
 - i. Flue Pipe: This pipe connects the chimney with the combustion chamber to ensure that smoke can escape smoothly.
 - j. Garbage Dryer Box: After the incineration process, the remaining garbage needs to be dried. This box serves to dry waste before it is disposed of or further processed.
 - k. Dryer Box Frame**: This frame supports the dryer box to keep it sturdy and not easily damaged.
 - l. Red Brick: Red brick is used as a building material for machine walls, providing good thermal insulation.
 - m. Brick Wall: This wall serves to retain heat and prevent heat from leaking into the surrounding environment.
 - n. Cleaning Hole: This hole facilitates the cleaning process of the machine after use.
 - o. Waste Holding Frame: This frame functions to hold waste from falling or slipping during the combustion process.
2. Machine Component Manufacturing Process

Machine frame manufacturing; The frame of the machine is made of strong steel material. The manufacturing process includes cutting, welding, and assembly. The frame must be designed in such a way as to safely hold all the components of the machine. Once completed, the frame is tested for strength to ensure it can withstand extreme conditions.

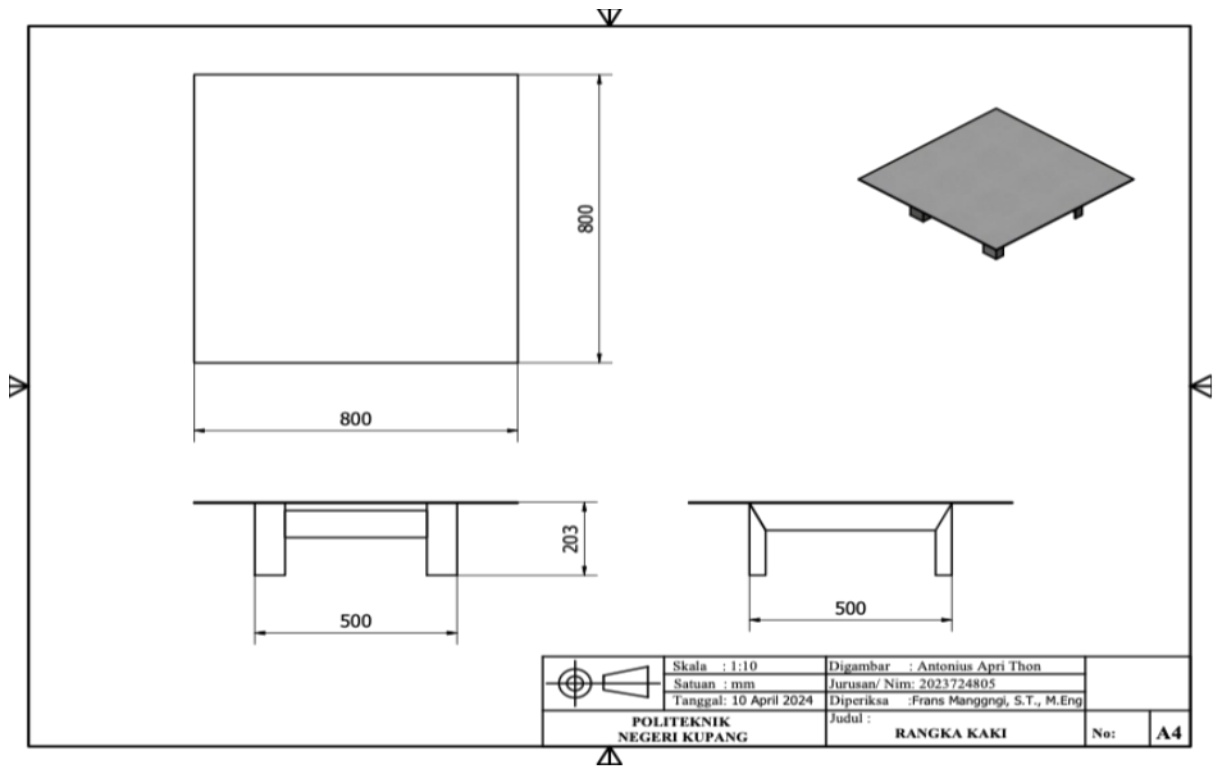


Figure 3. Main Frame

Manufacture of combustion chamber covers; The combustion chamber cover is made of heat-resistant metal material. The manufacturing process includes cutting and welding. This cover must fit snugly so that no smoke can escape from the combustion chamber.

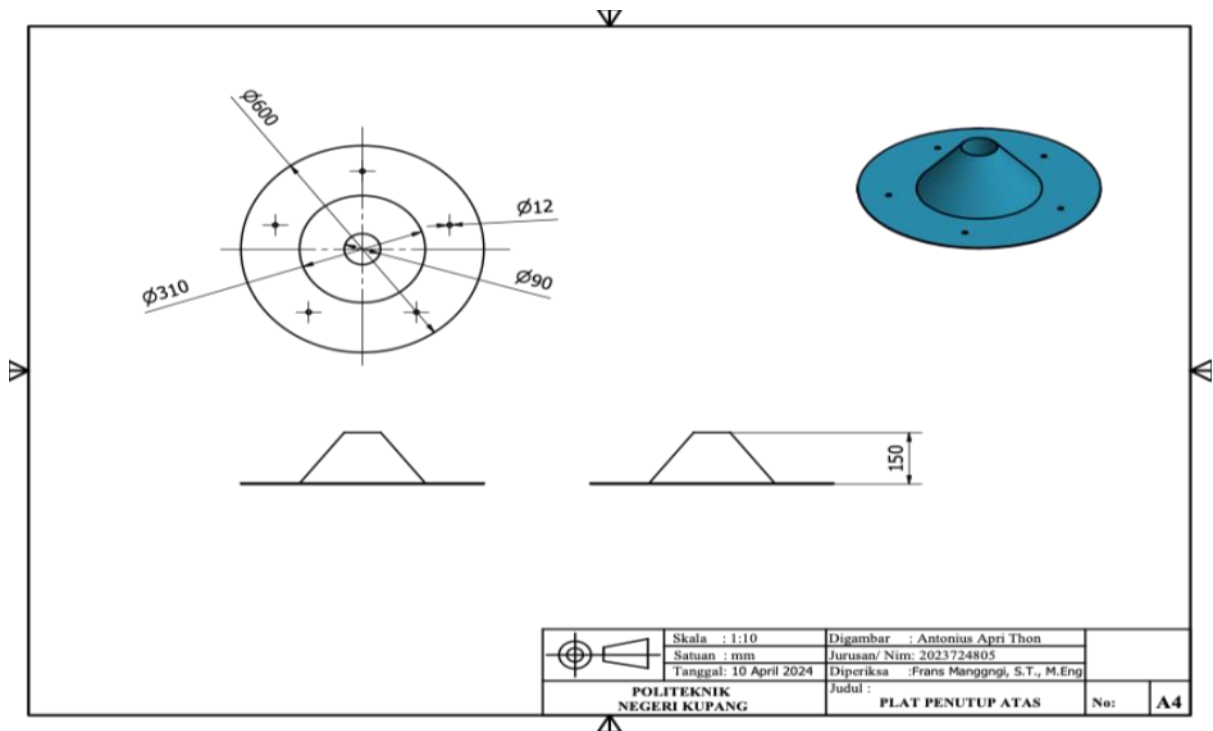


Figure 4. Combustion chamber cover

Manufacturing of Waste Entry Hoppers; Hoppers are made of strong, rust-resistant materials. The manufacturing process includes cutting and assembly. The hopper is designed with an angle that makes it easier for the user to insert the garbage.

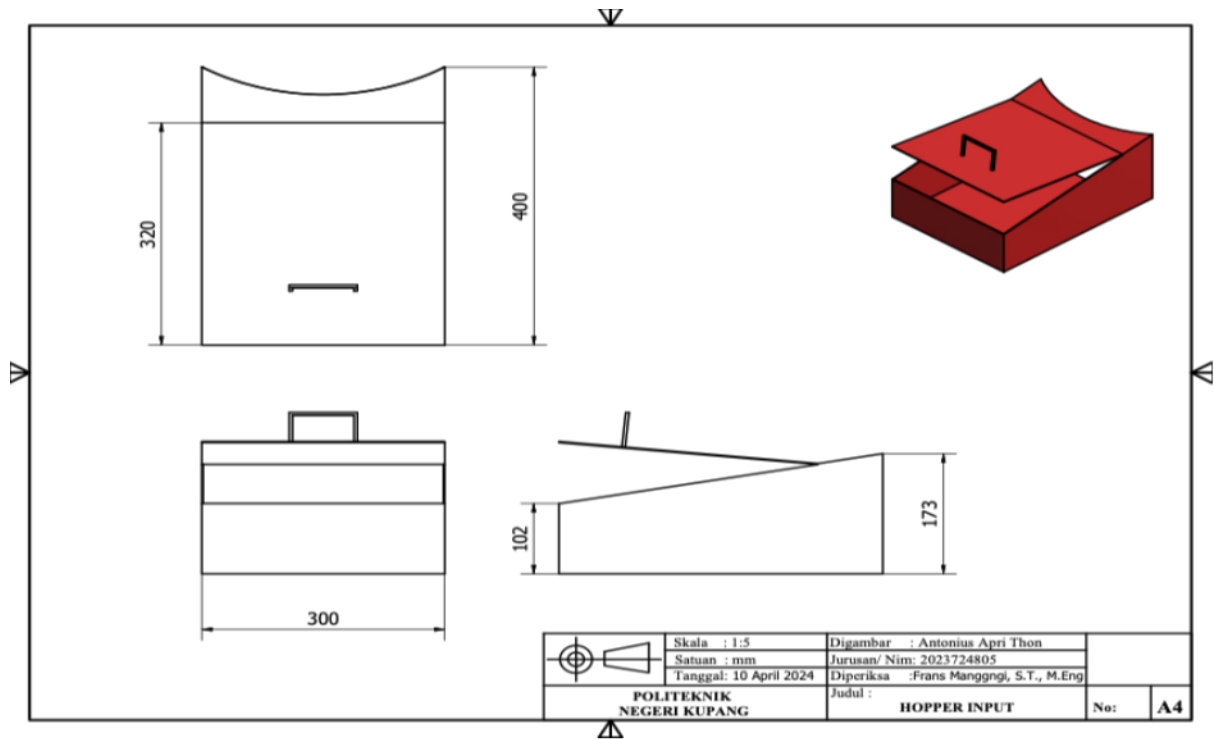


Figure 5. Hopper

Manufacture of ash collection boxes; The ash collection box is made of heat-resistant metal. The manufacturing process includes cutting, welding, and assembly. This box should be large enough to hold the ash from combustion.

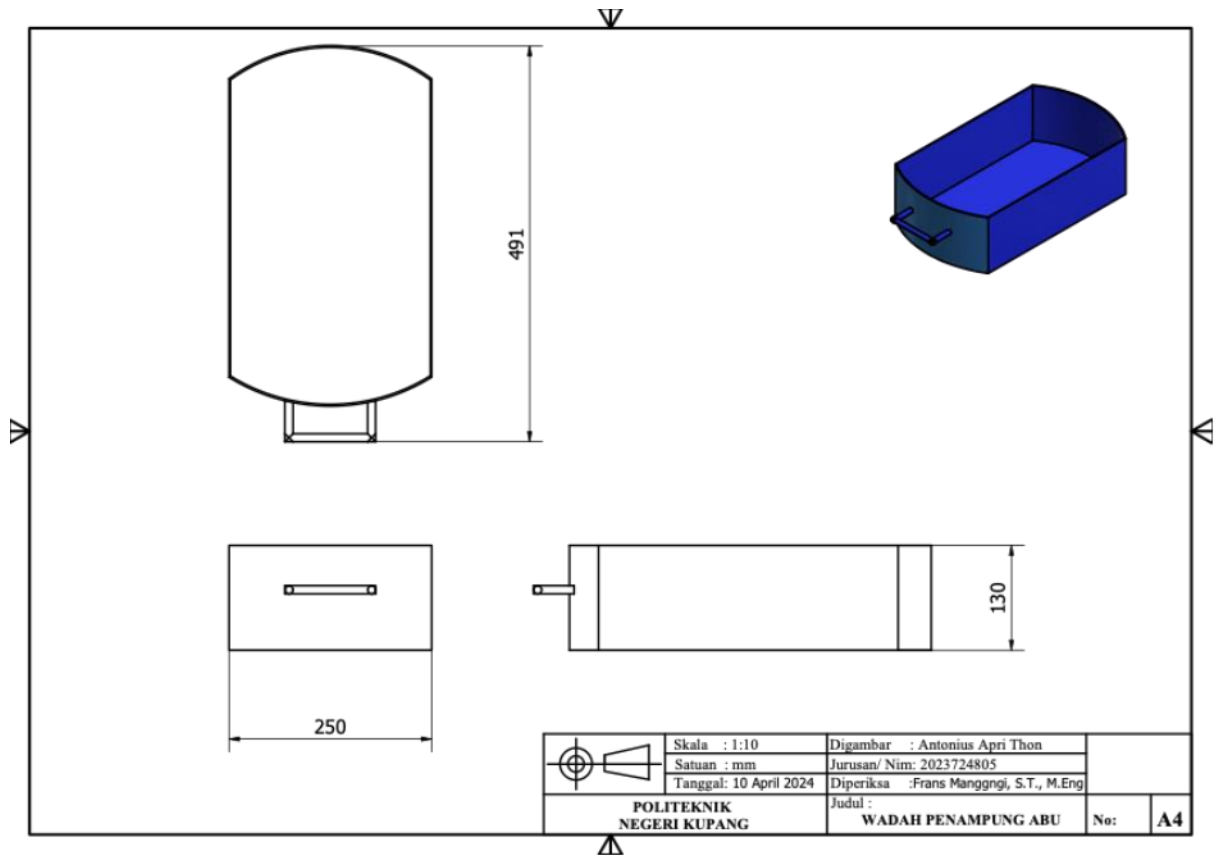


Figure 6. ash collection box

manufacture of combustion chamber cover plates; The cover plate is made of heat-resistant metal. The manufacturing process includes cutting and welding. This plate must fit snugly so that it can close the combustion chamber tightly.

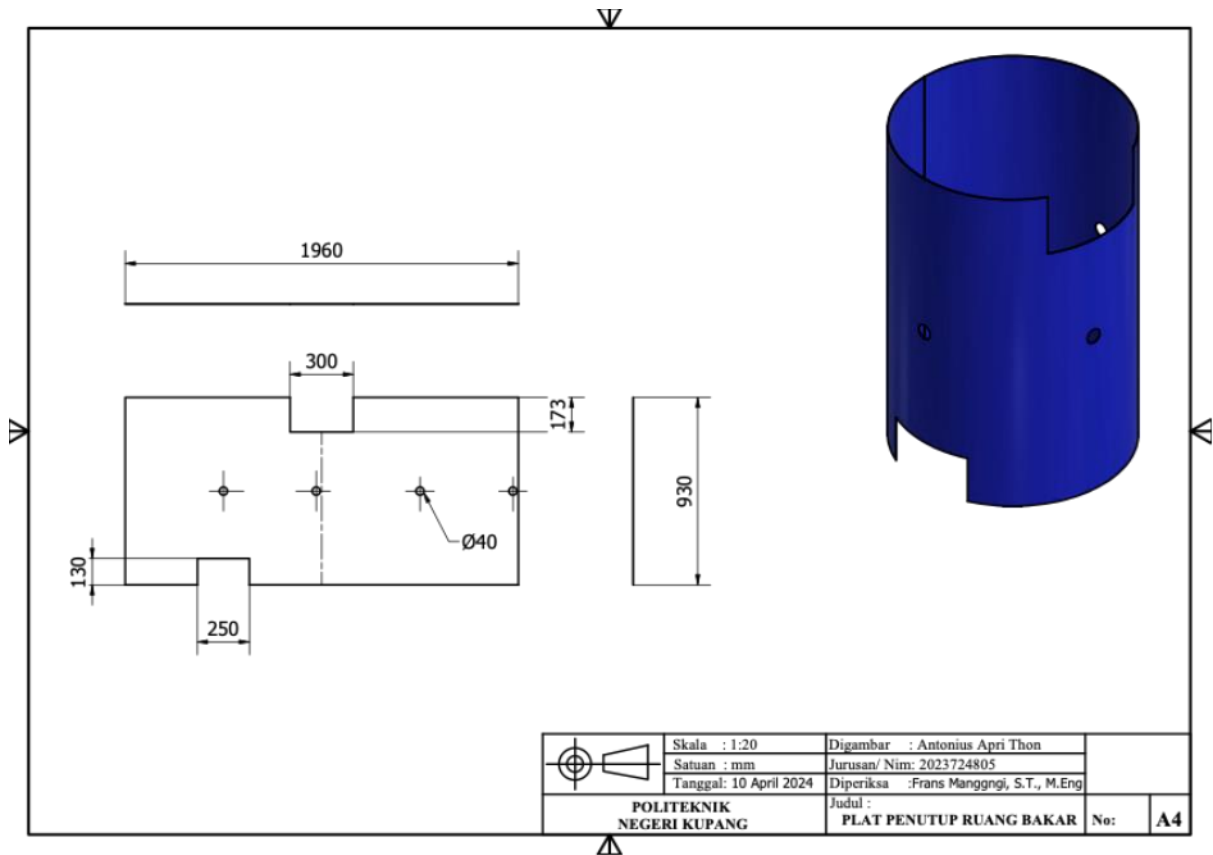


Figure 7. Combustion chamber cover plate

The manufacture of chimneys; The chimney is made of a metal material that is rust-resistant. The manufacturing process includes cutting and assembly. The chimney must be designed to drain smoke well and have a filtration system.

Manufacture of Flue Pipes; Flue pipes are made of heat-resistant metal. The manufacturing process includes cutting and welding. These pipes must be well connected between the chimney and the combustion chamber.

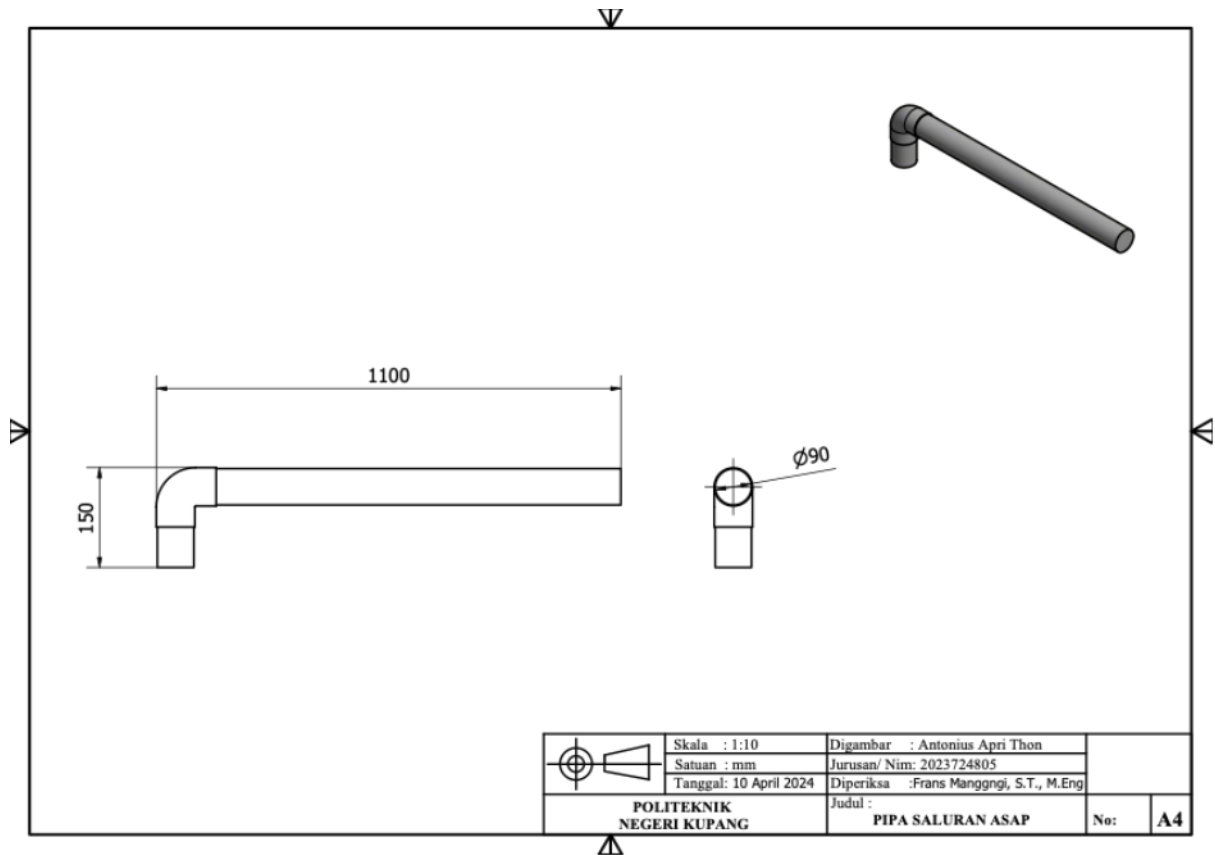


Figure 8. Smoke Duct Pipe

Garbage dryer box manufacturing; The dryer box is made of strong and heat-resistant materials. The manufacturing process includes cutting, welding, and assembly. This box is designed to dry waste efficiently.

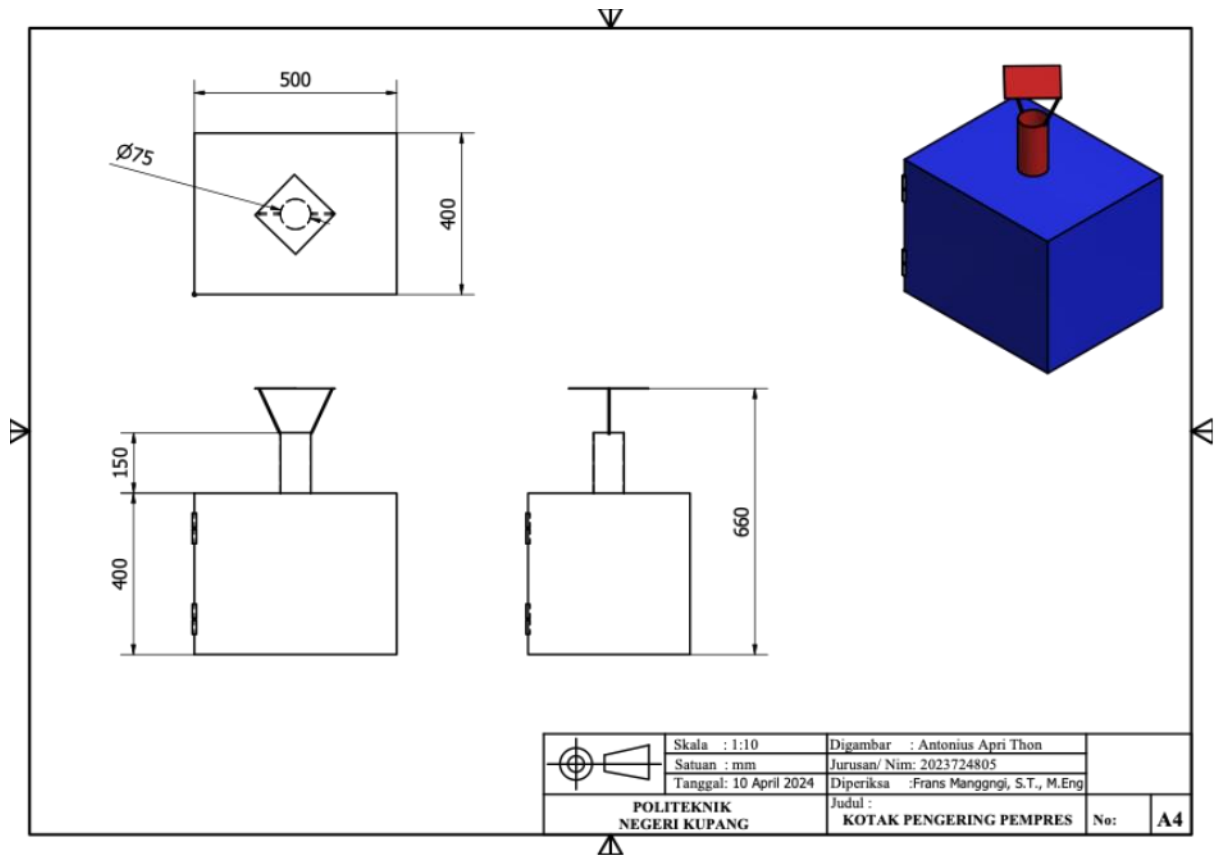


Figure 9. Garbage Dryer box

Manufacture of dryer box frames; The frame of the dryer box is made of strong steel material. The manufacturing process includes cutting and welding. The frame should be sturdy enough to support the dryer box.

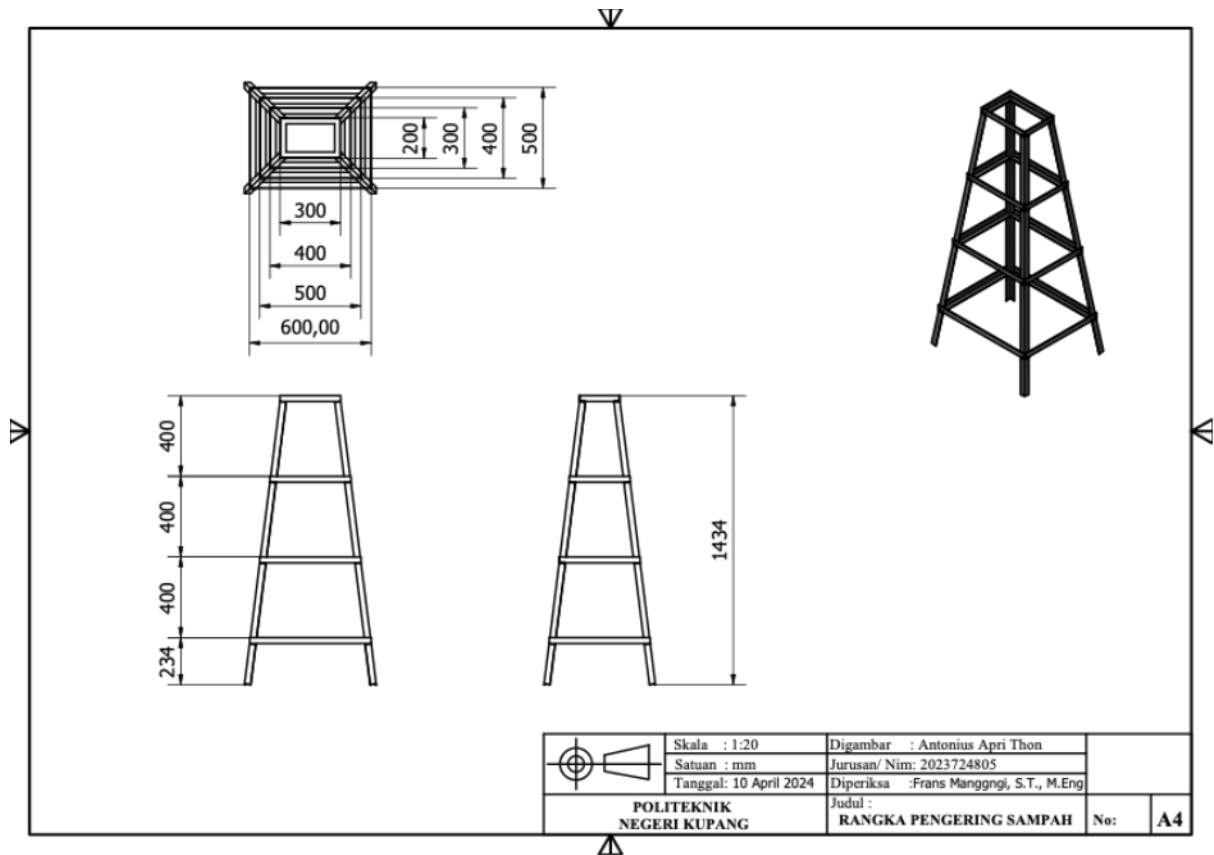


Figure 10. dryer box frame

Brick Walls: Red bricks are made through the process of burning clay at high temperatures. After the brick is ready, the brick wall is built with good installation techniques to guarantee strength and durability.

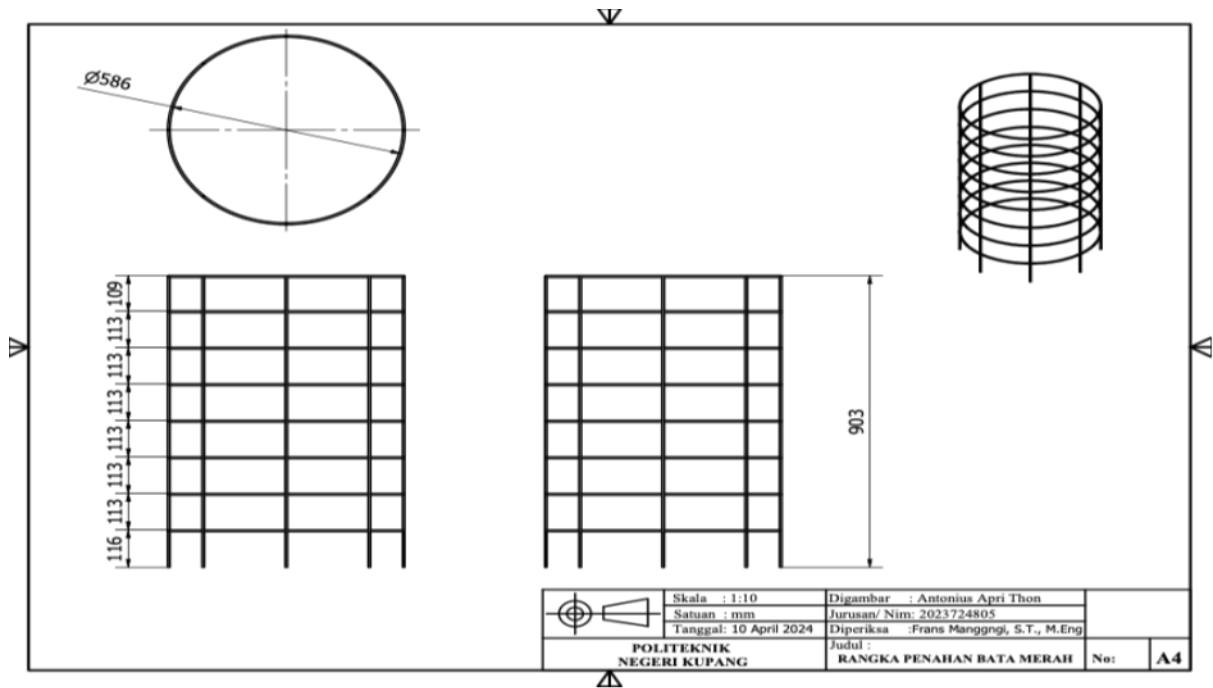


Figure 11. Didn't Have Kids

Cleaning Hole Manufacturing; The cleaning hole is made by cutting the machine wall in a strategic position to facilitate cleaning access. These holes should have a cover so as not to interfere with the combustion process.

Manufacture of Waste Holding Frames; The garbage retention frame is made of strong steel material. The manufacturing process includes cutting and welding. This frame must be designed to safely hold waste during the combustion process.



Figure 11. Brick Wall Making Process

3. Component Manufacturing Process Analysis

The process of manufacturing environmentally friendly waste incinerator components requires skills and experience in welding, cutting, and assembly techniques. Each component must be made with precision to ensure the machine is functioning properly. In addition, the selection of the right materials is essential to guarantee the durability and efficiency of the machine. The quality of each component greatly affects the overall performance of the machine. For example, a poorly functioning wind pump can result in an inefficient combustion process, while a poorly designed chimney can emit harmful fumes into the environment.

In the manufacturing process, testing each component is also an important step. Each component must be tested before being assembled into a whole machine to ensure there are no defects that could affect the performance of the machine.

Machine Performance Testing

After the prototype of an eco-friendly urban waste incinerator machine is successfully built, the next stage is testing to assess the performance of the machine in real conditions. Testing the performance of these engines involves various aspects, such as combustion efficiency, emission control, operational stability, and engine durability over a period of time. The results of the machine performance test can be described as follows:

1. Combustion Efficiency

- a. The first test is focused on the efficiency of the combustion engine in processing waste of various types, including organic and non-organic waste. The engine shows optimal performance with a combustion efficiency rate of up to 95%, which means that most of the energy generated from combustion can be utilized to the fullest.

- b. The combustion process takes place in several controlled stages, resulting in a more perfect combustion with little ash residue. In organic waste, machines are able to reduce the volume of waste by 98% after burning, while non-organic waste experiences a reduction in volume by 96%.
 - c. This success shows that the machine is capable of managing large amounts of waste with higher efficiency than traditional combustion methods.
 2. Exhaust Emissions Measurement
 - a. As part of the performance test, the exhaust emissions produced by the engine during the combustion process are measured. This measurement is carried out using emission test equipment that meets international standards to assess air quality.
 - b. The test results show that this machine produces very low gas emissions. The level of carbon dioxide (CO₂) emissions was recorded at only 315 ppm, still within the threshold set by environmental regulations in Indonesia are mandatory. The CO₂ limit in Indonesia for clean air is 310-330 ppm
 - c. In addition to CO₂, other emissions, such as carbon monoxide (CO), nitrogen oxides (NO_x), and fine particulate matter (PM), are also below the permissible threshold, which suggests that these machines are successful in significantly reducing air pollution.
 3. Performance Stability and Consistency
 - a. Further testing is carried out to assess the stability of the machine's performance under various operating conditions, including variations in the amount of waste and the type of waste burned. The machine shows stable performance in processing waste both in small and large quantities.
 - b. The automatic control system in the machine is able to adjust the combustion parameters in real-time, keeping the temperature and pressure optimal without manual intervention, so that the machine can operate without interruption for a long time.
 - c. In tests with higher processing capacity, the engine remains showing good efficiency and stability, without a significant decrease in combustion performance.
 4. Durability and Reliability of the Machine

To test the durability of the engine, a long-term test is carried out by running the engine for a sufficient time to see if there is any deterioration in performance or damage to the main components. This engine has proven to be durable, with no significant problems with the combustion system, structural components, or control system.

The automatic temperature monitoring system has also proven to be very effective in keeping the engine from overheating, and providing alerts when the temperature reaches the safe limit, thus preventing damage to the engine.
 5. Burn Time and Process Speed

The time it takes to complete the incineration process varies depending on the type of waste and the volume burned. This machine is able to complete the waste burning process within 30 minutes for organic waste as much as 100 Kg, and 60 minutes for non-organic waste of a certain size with a weight of 50 Kg.

This speed is quite efficient, especially when compared to open burning processes which often take longer and can produce harmful smoke and pollution.
 6. Operating Safety
 - a. Safety testing is carried out to ensure that the machine operates safely and does not pose a danger to the user or the surrounding environment. The engine is equipped with an automatic protection system that can stop the operation of the engine if there is a damage or disturbance in the combustion system.

- b. In addition, the internal fire extinguishing system works automatically in an emergency, such as if a temperature exceeding the safe limit or an unwanted fire is detected, ensuring that the risk of fire can be minimized.

The performance tests of the machines show that this eco-friendly urban waste incinerator is not only efficient in managing waste, but also successfully reduces the negative impact on the environment. With its high combustion efficiency, low exhaust emissions, and proven durability and operational stability, the machine is qualified for use in waste management in urban environments. Testing also confirmed that the machine is safe to operate and can work consistently on a large scale.

Environmental Impact Evaluation

As part of the research aimed at producing environmentally friendly waste incinerators, environmental impact evaluation is a very important stage to ensure that these machines are not only efficient in waste processing, but also have minimal impact on the quality of the surrounding environment. This evaluation involves several aspects, namely air pollution reduction, residual combustion control, and impact on the ecosystem. The results of the environmental impact evaluation can be explained as follows:

1. Air Pollution Reduction

One of the most significant impacts that can be caused by burning waste is air pollution, which often contains harmful gases such as carbon monoxide (CO), nitrogen oxides (NO_x), as well as fine particles. However, the test results of this machine show that the developed waste incinerator has an excellent capacity to control and reduce harmful gas emissions (Zhang et al., 2020).

This shows that the use of these machines can reduce the negative impact on air quality in urban areas and prevent air pollution that is harmful to human health and other living things.

2. Waste Incineration Management

The machine is designed to minimize the formation of hazardous combustion residues, such as ash and waste residues. Most of the waste that is burned will be converted into gas, while the remaining ash produced has a very small volume (Aderoju et al., 2017).

Test results show that this machine is able to reduce the volume of waste by up to XX%, and produces only a small amount of ash which is relatively easy to manage further. This residual ash can be reused as raw materials for making fertilizer or building materials, depending on the type of waste burned. This reduces the need for landfills (TPAs) and supports circular economy principles.

3. Impact on Ecosystems

Impacts on ecosystems related to the burning of waste that can produce harmful chemicals or ash that damage soil and water. The machine is designed with careful emission control to ensure that combustion by-products do not pollute the surrounding environment.

In the tests, no significant water or soil contamination was detected due to the combustion process, indicating that this machine has the potential to be an environmentally friendly solution for urban waste management.

4. Machine Performance in Waste Management in Urban Environments

- a. Environmental impact evaluation also includes sustainability aspects in urban waste management. These waste incinerators can reduce the volume of waste that goes into landfills, which are one of the main sources of soil and water pollution in major cities.

- b. With its high combustion efficiency and effective emission control, this machine not only serves as a waste treatment tool, but also contributes to efforts to reduce pressure on the increasingly limited capacity of landfills.
- c. The large-scale use of these machines in cities can help reduce landfills, reduce the burning of open waste, and reduce the overall negative impact on the environment.

Based on the results of environmental impact evaluation, this environmentally friendly urban waste incinerator has been proven to be able to have a significant positive impact in reducing air pollution, controlling residual combustion, and minimizing soil and water pollution. It also has the potential to support more sustainable waste management in urban areas, by reducing reliance on landfills and reducing negative impacts on ecosystems. Therefore, this machine can be considered an innovative and environmentally friendly solution to solve waste management problems in cities.

Potential Implementation in Urban Environments

The results of this study show that the designed waste incinerator has high efficiency in processing urban waste with minimal environmental impact. With environmentally friendly combustion technology, this machine can be an alternative solution in overcoming the growing waste problem in urban areas.

One of the main advantages of this machine is its ability to significantly reduce the volume of waste without generating large amounts of harmful emissions. With a tested emission control system, this machine can meet strict environmental standards, so it can be used in various urban areas without causing excessive air pollution.

In addition, the compact and modular design of the machine allows flexibility in applications at various scales, ranging from waste management facilities at the RT/RW level, offices, to small industrial scales. The implementation of this technology can also reduce reliance on conventional waste disposal methods such as landfills, which are increasingly difficult to manage in urban areas due to limited land.

From an economic point of view, the use of this waste incinerator can reduce transportation and waste management costs because waste can be processed directly at the source. In addition, combustion products such as ash residues can be reused as raw materials for the construction or fertilizer industry, increasing the added value of waste that was previously only considered a burden.

In the long term, the implementation of this technology is expected to support government policies in realizing a cleaner and more sustainable city. With regulatory support and incentives from local governments, this machine can become part of a more modern and environmentally friendly waste management system in urban areas.



Figure 12. Garbage Burning Machine Construction

CONCLUSION

With the development and implementation of this prototype waste incinerator, it is hoped that a more efficient and environmentally friendly urban waste management solution can be created, which can reduce reliance on open burning which is often harmful to health and the environment. This machine is expected to be an effective alternative in overcoming urban waste problems in the future.

Based on the results of environmental impact evaluation, this environmentally friendly urban waste incinerator has been proven to be able to have a significant positive impact in reducing air pollution, controlling residual combustion, and minimizing soil and water pollution. It also has the potential to support more sustainable waste management in urban areas, by reducing reliance on landfills and reducing negative impacts on ecosystems. Therefore, this machine can be considered an innovative and environmentally friendly solution to solve waste management problems in cities.

This research successfully designed and tested the performance of a garbage burning machine specifically designed for urban areas with environmentally friendly principles. The test results show that this machine is able to significantly reduce the volume of waste through an efficient and controlled combustion process. With an emission control system in place, the levels of pollutants produced remain within safe thresholds in accordance with environmental standards.

In addition, the machine's compact and modular design allows for flexible deployment at various scales, from residential environments, commercial areas, to small-scale waste management facilities. Another advantage of this engine is fuel efficiency and the potential use of combustion residues as a useful material, thus supporting circular economy principles in waste management.

With the results obtained, this waste incinerator has great potential to be implemented in urban environments as an alternative solution in overcoming waste problems. Proper regulatory and policy support from the government as well as optimization in machine operations will further increase the effectiveness of its use in creating a cleaner and more sustainable environment.

Based on the results of this study, it is recommended to make further refinements to the design of the machine so that it can be operated more efficiently in extreme weather conditions and on a larger scale. The application of this machine can be carried out in cooperation between local governments and the industrial sector to improve the quality of waste management and reduce negative impacts on the urban environment.

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