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Mechanical Design and Construction of a Sea Water Wave Power Plant Using a Buoy System

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Abstract

The need for electrical energy by society and industry has encouraged research to build electricity generation from new and renewable energy. The sea is a source of renewable energy, especially ocean wave energy. Mechanics for the design and construction of a floating system ocean wave power plant is a power plant that utilizes ocean wave energy with a two-floating system equipped with various components aimed at producing electric power. The aim of this research is to design and manufacture the mechanics of a sea wave power plant. The techniques used in making mechanical components are welding, cutting, smoothing, drilling and dynamo installation. The results obtained from this research are to design and build a mechanical system to produce ocean wave electricity. As a result of equipment testing in the mechanical systems lab, this wave power generator succeeded in lighting electric lights with an electric current output of around (0.01 – 0.02) Ampere and a voltage of (2.70 – 4.90) Volts with a float height of between (30 – 100) cm.

Keywords: Design, Power Plants, Sea Waves, Buoy Systems

1. INTRODUCTION

Energy has become a world problem for the next few years, while the energy sources used so far, such as oil, natural gas and coal, are non-renewable energy sources and are becoming increasingly depleted over time. This problem then encouraged many technicians and scientists to utilize energy from unlimited energy sources such as ocean waves [1].

Indonesia's sea area is three times larger than its land area, making Indonesia have a large source of energy to harvest or what is usually called the energy harvesting method. Energy Harvesting or energy harvesting is a process where energy originating from external sources of solar energy, heat energy, wind energy, potential energy and kinetic energy is captured and converted into electrical energy [2].

Energy use in Indonesia is still dominated by the use of non-renewable energy originating from fossils, especially petroleum and coal. However, as time goes by, the availability of fossil energy is running low and to anticipate this, new and renewable energy (EBT) is the best alternative. The use of new and renewable energy must be the main concern of the Indonesian government not only as an effort to reduce the use of fossil energy but also to create clean or environmentally friendly energy [3].

One of the renewable energy resources that can be utilized comes from the sea. The sea stores usable energy such as waves, wind, currents and tides. The dynamics of wave and wind energy come from different pressures between layers of the atmosphere, then energy is transferred from the wind to the waves. The energy transferred depends on the wind speed, the length of time the wind blows and the distance (fetch). In the process, solar power levels with a power of around 100 W/m2 are converted into waves with a power level of more than 1,000 kW [4].

The use of ocean wave energy as a source of electrical energy is actually not a new technology. Indonesia is a maritime country with an outer coastline of around 95,181 km. Under these conditions, the Indonesian region has great potential to create renewable energy sources originating from the sea. Ocean wave power plants (PLTGL) are power plants that use energy sources in the form of sea waves in waters or coastlines. PLTGL was created to obtain electrical energy by utilizing the kinetic energy of ocean waves. In general, PLTGL operates by converting waves to become a turbine (mechanical) drive tool which is then used to produce electricity [5].

In designing a mechanical model for a marine wave power plant, the buoy system is applied to the high seas in Indonesia. Sea water waves moving up and down will be used to move a buoy which is connected to the mechanical components of the design of a sea wave power plant and then rotates the other components and will produce electricity. The engineering design of a sea water wave power plant with a buoy system is a means of generating electricity by utilizing sea wave energy with a system of two buoys equipped with various components which aim to produce electricity [6].

The framework used in the design and construction of sea water wave power plants with a float system comes from several materials such as steel axles, plate iron, angle iron, bearings, gears, flywheels, floats, pulleys and dynamos. Mechanics of designing and building a sea water wave power plant which will be made using iron. Iron is used because it has the advantages of being difficult to damage, durable, strong and sturdy as a mechanical material. In making the mechanics of designing and building a sea water wave power plant, several aspects of work are divided into aspects including design, mechanics and equipment testing. In this research, we try to create a mechanical design for a seawater wave power plant that focuses on mechanical aspects with the concept of iron as the basic material [7].

The aim of this research is to create a mechanical design for a seawater wave power plant with a buoy system, to utilize energy originating from marine resources. Meanwhile, the benefit of this research is that it can utilize sea wave energy as renewable electrical energy by using sea wave energy conversion designs..

2. METHODOLOGY

2.1. Research Location

This research was carried out on March 1- April 25 2023 at the Teaching Factory (TEFA), Marine Engineering Study Program, Karawang Marine and Fisheries Polytechnic, and Cilamaya Science and Technology Vocational School, Karawang.

2.2. Tools and materials

In this research, tools and materials are needed that are used according to their use to help with the work that has been planned. The following are the tools and materials used.

Table 1. Tools used

No	Tool	Usage
1.	Mesin Las	To weld metal designs and components
2.	Grinding	To cut design iron and smooth
3.	Drilling machine	To drill a hole in the bearing installation

Table 2. Materials used are

No	Material	Usage
1.	Flywheel	To increase rotation speed (flywheel)
2.	Small pulley	To help rotate the dynamo
3.	Iron axle	To unite Bearing, Gear, float flywheel.
4.	Bearing	To help rotate the axle and wheel iron.
5.	Chain	To transmit rotation from small gear to large gear.
6.	Iron elbow	To make a design coaster
	Vambelt	To rotate the large pulley to the small pulley
9.	Lifebuoy	To swing/rotate the iron axle.
10.	Big pulley	To rotate the small pulley
11	Dynamo	To generate electricity

2.3. Marine Resources for Electrical Energy

There are several sea water resources for generating electrical energy, including: [8]

1) Ocean Wave Energy
   The kinetic energy contained in sea waves is used to drive a turbine, then the turbine will drive a generator or dynamo.
2) Sea Tides
   High tide is collected in the reservoir, then when the water recedes, the water behind the reservoir is channeled to drive the turbine.
3) Differences in Sea Water Temperature
   Generating electricity with differences in sea temperature by utilizing temperature differences to drive turbines.

2.4. Ocean Wave Power Plant (PLTGL)

Ocean wave power plants (PLTGL) are an electricity generation technology that utilizes ocean wave energy. Ocean wave energy is one of the energy potentials in the ocean that can be utilized to generate electrical energy. Sea wave energy is energy resulting from the movement of sea waves towards land, and vice versa. Sea waves arise due to the movement of the sea due to the push of wind movements. Because the energy source continuously exists due to natural phenomena, ocean wave energy is included in renewable energy [9].

Ocean wave power plants generally use oscillating water column technology. PLTGL has several core components that play a role in producing electrical energy, namely the mechanical components for ocean wave energy conversion, turbines and generators. The way PLTGL works is that the potential ocean wave energy is captured by the mechanics of the ocean wave energy conversion machine. In the conversion machine, kinetic energy is produced by sea waves which is then transmitted to the turbine. The turbine then rotates to produce mechanical energy from the kinetic energy of sea waves in the conversion machine. After the turbine moves, its rotation is transmitted to the generator and produces electrical energy [10].

2.5. Ocean Wave Energy Conversion Techniques into Electrical Energy

Basically, the working principle of technology that converts sea wave energy into electrical energy is to accumulate sea wave energy to rotate a turbine which is passed on to a generator. According to Valen Tae in [11] capturing wave energy can be done by:

a) With a float
   This device is used to generate electricity from the vertical and rotational movements of a buoy and can be moored to a floating raft or a device anchored to the seabed.
b) Oscillating Water Column (OWC)
   This water column oscillation device will capture wave energy that hits the opening of the oscillating column door, resulting in fluctuations or oscillations of water movement in the oscillating column space, then this air pressure will move the turbine blades which are connected to an electric generator to produce electricity.
c) Tapchan System
   The tapchan system is installed in a canal structure built on the beach to concentrate waves and channel them into an elevated artificial pool structure. The water that flows out of the holding pond is used to generate electricity using standard hydropower technology.

2.6. Data Collection

Literature review

This stage is used as a search for information and references to collect data related to the mechanics of designing a sea water wave power plant with a buoy system, such as the basic materials used, how to make it, how to test the mechanics of designing a sea water wave power plant with buoy system sourced from several literatures such as scientific journals, theses, and the internet.

Observation

Observations were made by understanding and planning the basic materials that will be used to make wave energy conversion components by considering several things such as mechanical strength and the strength of the material when in water. As well as analyzing the results of mechanical component testing to evaluate deficiencies so that the tool or mechanical component can function properly. After the assembly and component joining process is complete, the conversion tool is tested in the mechanics laboratory to determine the output of the tool.

2.7. Research Stages

In this research, several stages were carried out: namely:

a) Studies literature

The first stage was to collect literature related to mechanical systems for wave energy conversion, such as the basic materials to be used, manufacturing methods and testing methods.

b)Mechanical system design

At this stage plan / design and determine the materials that will be used in the mechanical components that will be built. After the design is made, every tool and material is collected. The basic materials that will be made use plate iron, elbow iron and cast iron as the main frame.

c) Manufacturing of mechanical components

After designing and determining the mechanical materials, the next stage is the manufacturing process. Where this process is carried out directly by cutting, smoothing, assembling and coloring.

d) Mechanical component testing

At this stage the mechanical components that have been made will be tested, the strength of the wave energy conversion device and the deficiencies analyzed to ensure the components can function properly.

e) Finishing

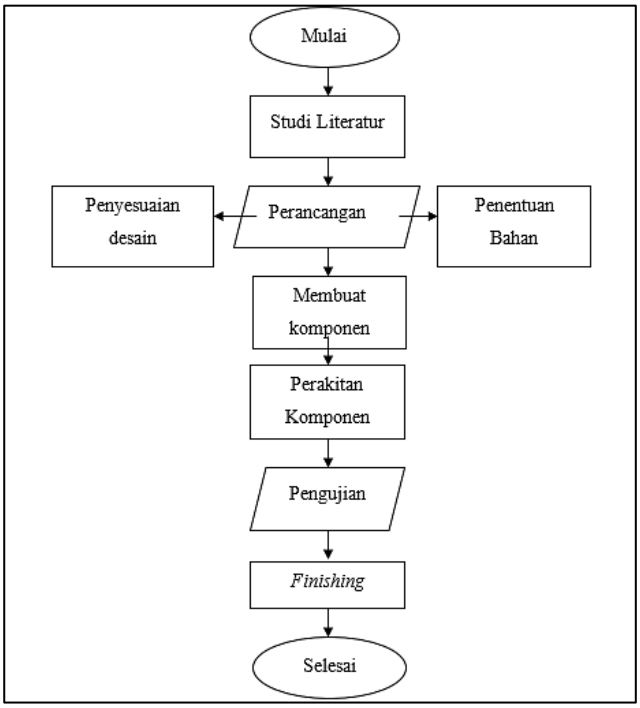
After all stages have been completed, the final stage is to combine all the components that have previously been confirmed to function properly.

f) Lab test

Carry out manual testing of the tool in the mechanics lab by pulling the buoy up and down as a substitute for waves lifting the buoy.

2.8. Research Flow Chart

The work flow for designing a mechanical system based on sea wave energy can be illustrated with a flow diagram as follows:



Gambar 1. Digram alir penelitian

2.9. Workshop Work

This stage is carried out for the process of making mechanical components which is carried out in the workshop, starting from making the cover, welding the design, installing and assembling all the components into one. By preparing the basic materials that will be used to make components, the process of cutting, polishing, welding and combining all components into one complete tool is carried out.

The steps for assembling the container and components are as follows:

1) Prepare the basic materials that will be made, namely angle iron, axle iron, bearings, gears, flywheels, floats, chains, pulleys, dynamos.
2) Take measurements on the appropriate part of the angle iron as planned then cut it
3) Weld the angle iron parts that have been measured and then put them together using a welding machine.
4) Drill the tool design on the right and left to install the bearing.
5) Installing components such as gears, pinions, wheels and large pulleys
6) Install the vambelt on the large pulley and then distribute the vambelt to the small pulley which is integrated with the dynamo.
7) Attach the float that has been prepared and glue the float to the swinging iron of the tool.
8) Assembly or unification of all components into one complete sea wave conversion tool body,
9) Carrying out tool testing

3. RESULTS AND DISCUSSION

This wave energy conversion tool is moved using a float as the main mover. The waves will move the float which rotates the gear, flywheel and pulley which then moves the kinetic energy which is transmitted to the dynamo which will produce electricity.

3.1. Tool Planning

The design stage is designing a sea wave energy conversion tool using two gears, two iron axles, two pulleys, one flywheel and one chain and one dynamo. The materials used include hole angle iron as a body or support, iron plate as a frame cover and mounting components for the wave energy conversion device being made. The tool design view is shown in figure (2-6).

a. Front View Tool Design:

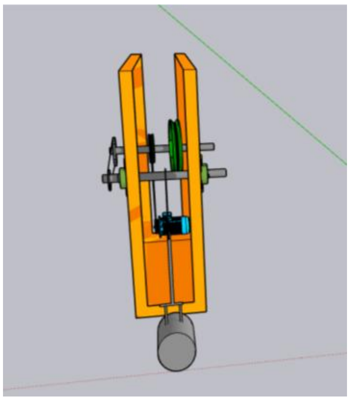
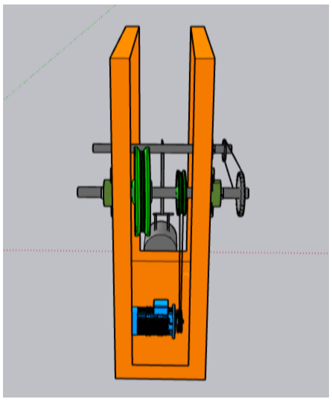


Figure 2. Front view of the tool design

The design of the front view of the sea wave energy conversion tool is shown in Figure 2, which is the appearance that can be seen from the front side. From this side you can see several components such as the front frame, front gear, flywheel, float and pulley.

b. Back view tool design :



Gambar 3. Rancangan tampak Belakang

The rear view design of the ocean wave energy conversion device looks like in Figure 3, which is the appearance that can be seen from the back side. From this side we can see several components such as the rear frame, flywheel, upper and lower pulleys, rear gear and dynamo.

c. Right View tool design:

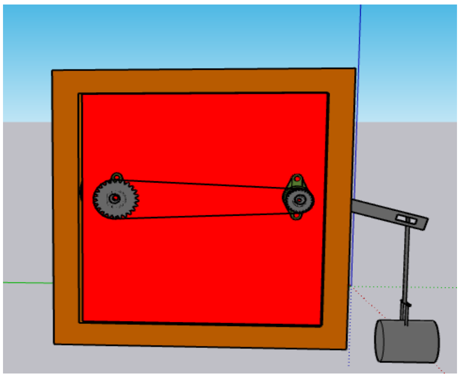


Figure 4. Design seen on the right

The design of the right view of the sea wave energy conversion tool on the right body frame design shows the tool view from the right side. This design displays several components such as the right frame and right bearing, small gear, large gear and chain.

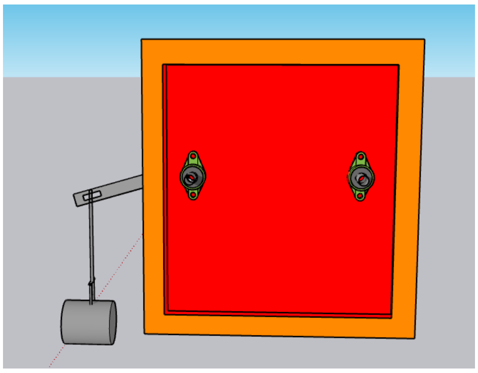


Figure 5. Left view of the design

d. Tool design Left View:

The design of the left view of the ocean wave energy conversion tool in the frame design of this framework shows the tool view from the left side. This design displays several components such as the left frame, left bearing.

Top View tool design::

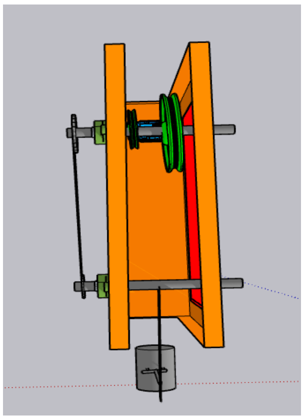


Figure 6. Top view of the design

The top view design of the sea wave energy conversion tool is the viewing angle of the tool when viewed from the top side. From this side we can see several tool components, such as the upper frame, upper gear, upper flywheel, upper pulley and upper bearing.

3.2. Making Tool Frames

After designing the tool, the tool is then made according to the design. At the frame manufacturing stage, all parts in the design of the wave energy conversion tool are made and adjusted to the specified sizes. The frame for the wave energy conversion tool is designed with dimensions: 80 cm high, 100 cm long and 40 cm wide.

3.3. Tool Component Size

In designing a sea wave energy conversion tool, several components are needed, where these components are used to convert sea waves into electrical energy [12]. The dimensions of the conversion tool components are listed in table 3.

Table 3. Structure sizes of wave energy conversion devices

Tool Models	Component Dimensions	Size
Ocean Wave Energy Conversion Tool	Frame Length	100 cm
	Frame Width	40 cm
	Frame Height	80 cm
	Flyheel diameter	24 inch
	Large pulley diameter	14 inch
	Small pulley diameter	8 inch
	Front Gear Diameter	16 cm
	Chain diameter	65 cm
	American iron length	60 cm

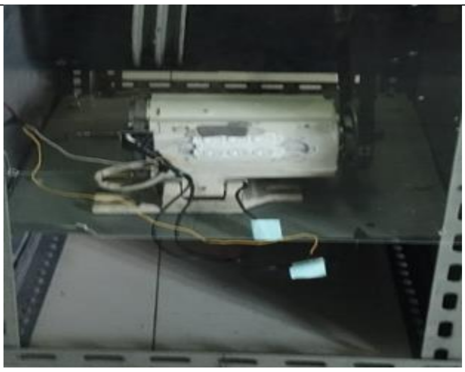
3.4. Frame Assembly

Assembling the mechanical frame of the wave energy conversion tool starts from cutting the perforated angle iron which is made as the tool frame by following the design that has been made. The cuts start from the mechanical frame, top frame, sides and front frame. The materials that have been cut are then combined using bolts according to the design.

Assembling the components of a sea wave energy conversion device is the process of putting together the necessary components of the device. In assembling it requires several processes and stages that are used in accordance with the design that has been created.

3.5. Installation of Tool

Components Installation of the ocean wave energy conversion tool components on the frame that has been made, starting from installing the gear, chain, flywheel and pulley on the iron axle that has been connected to the bearing. Installation of tool components on the conversion tool is shown in (figure 7-10)

 Figure 7. Framework Assembly	 Figure 8. Combination of Angle Iron
 Figure 9. Dynamo Support	 Figure 10. Dynamo installation

After the tool components are installed, the next step is to make a dynamo support on the frame of the wave energy conversion tool. Then install the dynamo on the dynamo support that has been made on the frame of the wave energy conversion tool.

3.6. Tool Shape

After assembling the tool frame and installing the necessary components, the shape of the equipment for sea wave energy conversion can be seen. The display of the installed ocean wave energy conversion tool is shown in (figure 11-14).

 Figure 11. Front View Tool	 Figure 12. Tool Left View

Figure 13. Top View Tool

Figure 14. Right View Tool

3.7. Experiment Simulation Tools

The design of a sea wave energy conversion tool is an innovative product that is capable of converting sea waves into electrical energy. This tool can be used as an alternative tool by coastal communities or small islands to obtain electrical energy.

Devices for converting ocean wave energy into electrical energy can be moored to wave breakers or can also be placed near the beach where the waves break. The device must be placed firmly so that when waves hit the buoy the device does not shake or bounce.

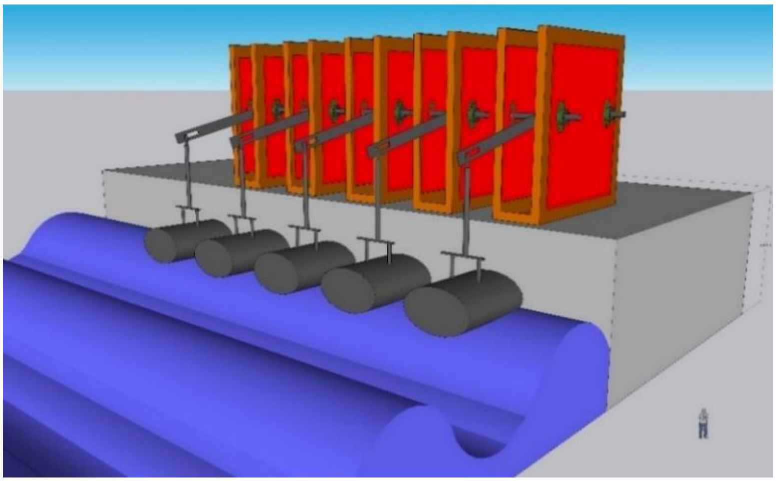


Figure 15. Simulation of Wave Energy Conversion Equipment

The working principle of the sea wave energy conversion tool depicted in Figure 15 is that the buoy moves up and down according to the movement of sea waves. Waves have force and when they hit a buoy placed in the sea, the wave exerts force on the object. The force exerted by waves is periodic and mainly depends on the wave height [13]. The movement of the float exerts a rotational force on the Gear and Pulley. The rotation of the pulley is channeled to the generator to convert ocean wave energy into electrical energy. The electrical energy produced can be stored in batteries or used directly to power electric lights.

3.8. How the Tool Works

Sea wave power plants basically have a working principle, namely converting sea wave energy (mechanical energy) into electrical energy. The accumulated ocean wave energy will rotate a turbine connected to a generator so that it can produce electrical energy [14]. This tool works by using the movement of sea water waves, sea water waves hit the buoy, the buoy which is hit by the wave movement gives rotation to the iron axle which has been installed by the bearing then gives its rotation to the big gear, the big gear connects its rotation to the small gear which has been installed with a chain continues to rotate the flywheel, the flywheel rotates the large Pulley, then the large Pulley moves the small Pulley and the small Pulley moves the dynamo then the dynamo produces electricity.

3.9. Tool Testing

Equipment testing was carried out on a laboratory scale at the Karawang Marine and Fisheries Polytechnic. The tool movement test was carried out using the swinging movement of the human hand on the buoy, which is likened to the movement or height of waves in the ocean. The movement variations were divided into three heights, namely 30 cm, 60 cm and 100 cm, where each float height was carried out 10 times. From the results of testing the device, it was obtained that at a float height of 30 cm, electrical energy was obtained with an average output voltage and electric current of 3.55 V/ 0.02 Ampere, at a height of 60 cm the average voltage and current output was 4.90 V/ 0.02 A and at a height of 100 cm, a voltage and current output of 70 V / 0.01 A is produced. Data on the test results of the equipment are written in Table. 4

Table 4. Test results of the tool with variations in float height

No	Height 30 cm Voltage and Current	Height 60 cm Voltage and Current	Height 1000 cm Voltage and Current
1	4.05 V / 0.02 A	6.18 V / 0,03 A	3.05 V / 0.02 A
2	3.37 V / 0.02 A	7.40 V / 0.03 A	3.88 V / 0.02 A
3	4.93 V / 0.03 A	6.91 V / 0.03 A	2.37 V / 0.01 A
4	3.74 V / 0.02 A	3.61 V / 0,02 A	1.90 V / 0.01 A
5	2.95 V / 0.02 A	4.61 V / 0.02 A	2.03 V / 0.01 A
6	2,69 V / 0.01 A	6.40 V / 0.03 A	2.83 V / 0.02 A
7	3,56 V / 0.02 A	3.37 V / 0.02 A	3.15 V / 0.02 A
8	2.91 V / 0.02 A	3.96 V / 0.02 A	2.34 V / 0.01 A
9	4.88 V / 0.03 A	3.20 V / 0.02 A	2.37 V / 0.01 A
10	2.49 V / 0.01 A	3.39 V / 0.02 A	3.15 V / 0.02 A
	Average		
	3.55 V / 0.02 A	4.90 V/ 0.02 A	2.70 V/ 0.01 A

From table 4 it can be seen that at a wave height of 30 cm, which is the height of the buoy, it produces an average electrical output (voltage) of 3.55 Volts (V) and an average electric current of 0.02 Ampere (A), while for a float height of 60 cm the average electric voltage output is 4.90 V and an average electric current of 0.02 A and for a float height of 100 cm it produces an average electric voltage of 2.70 V and an average electric current of 0.01 A.

4. CONCLUSION

Based on the results of mechanical trials on the design and construction of a seawater wave power plant with a buoy system, it shows that the designed device can produce electrical energy. As a result of equipment testing in the mechanical systems lab, this wave power generator succeeded in lighting electric lights with an electric current output of around (0.01 – 0.02) Ampere and a voltage of (2.70 – 4.90) Volts with a float height of between (30 – 100) cm. Component rotation can affect the energy produced based on the test results above, the higher the manual swing, the less energy is produced. Because density and gravitational force influence the rotation of the components.

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