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Development of a Prototype of a Hydroelectric Power Plant Based on Boyle's Flask as a Science Teaching Material

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Abstract: Boyle's flask is an innovation by scientist Robert Boyle which utilizes gravity and water which can move continuously without external energy, but the results of his research have not yet been used to become a prototype for a power plant even though in theory it already meets the criteria to become a prototype for a power plant. This research aims to determine the design and development of a Boyle's flask-based hydroelectric generator prototype as science teaching material and to measure the amount of output power produced from the Boyle's flask-based hydroelectric generator prototype. The method used is development using the ADDIE model. The results of this research are: the design of a Boyle's flask-based hydroelectric power plant prototype as science teaching material and the magnitude of the electric current produced from the Boyle's flask-based hydroelectric power plant prototype and an analysis of the relationship between the size of the Boyle's flask-based hydroelectric power plant prototype. flask with a strong electric current that is produced cannot be done because liquid substances, namely water and salt water, cannot flow endlessly even though there have been changes in several variables (using 2.5 inch and 0.25-inch hoses, using water and salt water which have different densities).

Keywords: Boyle's Flask, Teaching Materials, Science

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Introduction

The rapid development of science, especially science (IPA) and technology, on the one hand, does provide many benefits for the provision of various human needs. But on the other hand, this is also a (tough) challenge for educators to be able to prepare a generation of people who are literate (literate) in science, namely people who are able to open their sensitivity, observe, filter, apply, and contribute to the development of science (and technology) itself to improve the welfare and benefit of the community (Subiantoro, 2014). Like other subjects, science learning also requires teaching materials (Dadi, Redhana, and Juniartina 2019; Habib, Astra, and Utomo 2020; Ichsan et al. 2018; Nur Afinni Dwi Jayanti, Susilo, and Suarsini 2017; Shofa, Redhana, and Juniartina 2020; Utami and Atmojo 2021; Yamin and Karmila 2020) which is a challenge for science educators, namely providing teaching materials that make students have the character of caring for the environment, including understanding the problems around them because this will have an impact in the future (Irfianti, Khanafiyah, and Astuti 2016; Naziyah et al. 2020) One of them is about the availability of energy, especially electrical energy which is indispensable in development (Boedoyo 2013). The majority of power plants currently use coal (National Energy Council Secretary General Team 2019), but environmental pollution and the availability of raw materials will gradually dwindle (Vassilev, Vassileva, and Vassilev 2015), making coal-fired power plants and fossil fuel-based power plants will be abandoned in the future. The discovery of renewable fuel sources is very important to answer the problem of limited fossil-based fuel energy in meeting the increasing energy needs (Gultom 2018). Although renewable energy has been used as a power plant, each

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energy source has weaknesses such as the availability of sustainable biomass resources for biofuel production and biochemistry (Field, Campbell, and Lobell 2008) Geothermal energy has disadvantages such as high initial investment, long payback time and construction time, difficulty in assessing resources and difficulty in modulating (Li et al. 2015). Hydropower plants also have weaknesses which researchers found in July 2022 when researchers tried to model a hydropower plant in an artificial lake behind the Science Building of UIN Fatmawati Sukarno Bengkulu. When making the dam, it turned out that the researcher found that it took time to be able to reach the minimum height to be able to turn the pinwheel. In addition, the water that comes out of the dam sangat deras dan membuat tanah menjadi tergerus yang menyebabkan kerusakan pada tanah padahal ukuran bendungan ini termasuk kategori kecil. Apalagi jika ukurannya besar maka bendungan mengganggu aliran sungai dan dapat merusak ekosistem lokal, dan membangun bendungan dan waduk besar sering kali melibatkan pemindahan orang dan satwa liar adalah kerugian dari energi tenaga air (Bagher et al. 2015). Kelemahan energi matahari yang jatuh pada fotoelemen pada sudut tertentu tergantung pada klimaks lingkungan, musim, dan lokasi. Perubahan atmosfer juga menyebabkan perubahan sinar transversal dan sinar langsung, yang tidak mengubah cahaya, spektrum dan intensitas cahaya jatuh(Jakhongir Turakul ugli 2019). Kebisingan, kematian burung, kematian kelelawar, emisi gas rumah kaca dan dampak permukaan tanah adalah kerugian dari energi angina (Jaber 2014; Wang and Wang 2015)

Dalam analisis peneliti, pembangkit listrik tenaga air ini dapat diubah menjadi lebih *enviroment friendly* dengan merubah pola bendungan menjadi pola tertutup seperti rancangan dari Robert Boyle yang dikenal dengan nama *Boyle's flask* yang mana sistem ini memungkinkan cairan untuk menggerakan generator listrik tanpa energi dari luar (Mahesh 2018). Secara desain, dapat digambarkan seperti ini

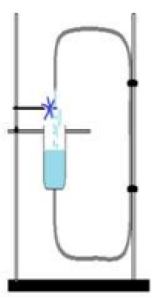

Figure 1: Design of *Boyle's flask*

Figure 2: The shape of Boyle *'s Flask*
(Mahesh 2018)

There are already people who have made hydroelectric models (Jawahar and Michael 2017; Nasir 2014; Tapia, Reina, and Millán 2020) and there are already those who have made prototypes with various shapes and types (Aida Syarif, Yohandri Bow1, KA Ridwan1, Delvi Karlini 2019; Devira Ramady et al. 2021; Doly brata siregar, Heri suripto, and Purwo Subekti 2022; Fahmi Arif Maulana1, Mohammad Ramdani2 2017; Nuriskasari et al. 2021; Ozdemir and Orhan 2012; Praptodiyono et al. 2021; Yahya, Munim, and Othman 2014; Zebua et al. 2019) but until now no one has made a prototype of a hydroelectric power plant based on *Boyle's flask* and their research has not been applied in the world of education. However, there is a type of research similar to the researcher's research, namely the making of prototypes/miniatures of hydropower plants as a learning medium for the high school level (Abdilah 2015; Rokhman et al. n.d.) However, this research has a weakness, namely that the water that has rotated the turbine must be pumped back using a machine and when there is no electricity from PLN, this system will stop, some even make a hybrid (a combination of hydropower and solar power plants) (Rokhman et al. n.d.) , the researcher analyzed that the weakness of solar power plants is the high price of each component so that their research products cannot be brought into the classroom. There are also those who make wind power plant modeling as a learning medium (Markumningsih, Purwantana, and Gulo 2019; Sugeng et al. 2019) and some even combine it with solar cells (Ridwan, Yuliani, and Syar 2021) the development of wind power plant prototypes is difficult to implement in Bengkulu because of the frequent storms here (Bengkulu 2022).

If translated into Indonesian Language means Boyle bottle (Translation 2022) which is the work of Robert Boyle and this is his design

flask
(Veproject1 2020)

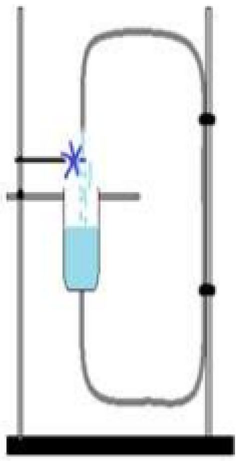

Figure 3: Design of Boyle '*s flask*

It is a type of electric generator by passing the liquid itself through a flask that flows itself without any external energy. By flowing a low-viscosity liquid through *Boyle's flask* which has the purpose of generating electricity without external energy or working to drain the liquid without any additional energy input. The advantage of *Boyle's flask* is that the generator is self-flowing, reliable and sustainable. Furthermore, self-flowing generators do not depend on nature for their own fuel, unlike other sources of electricity such as diesel, fossil fuels, biofuels, etc. And the generator that flows itself does not leave a negative impact on the environment. Another thing is that self-flowing generators are the least expensive source of energy when compared to traditional power generation methods and self-flowing generators are clean, affordable energy.

There are 2 research objectives carried out in this study, namely: to find out the design and development of a prototype of a hydropower plant based on Boyle's flask and to measure the amount of output power produced from a prototype of a hydropower plant based on Boyle's flask.

Method

This study uses a development research method from Dick et al, namely the ADDIE model, the model consists of five stages of development (Albet Maydiantoro 2019).

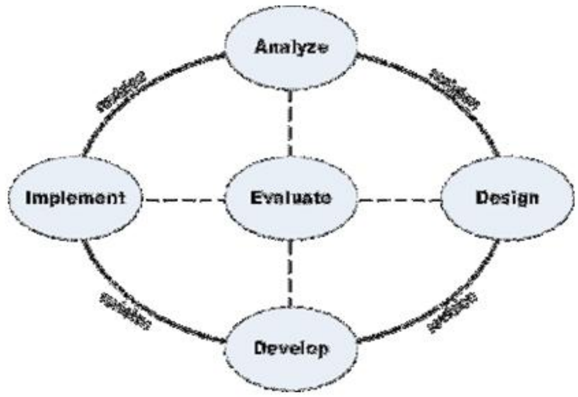

Figure 4: ADDIE Development Steps

ADDIE Development Research Model Stage

1. *Analysis*

   In the ADDIE development research model, the first phase is to analyze the need for new product development (models, methods, media, teaching materials) and analyze the feasibility and conditions of product development. The development of a product can be started by a problem in an existing product. There are already those who have made hydropower plant modeling as a teaching material in the classroom, but based on the analysis of researchers who have been studied in previous studies, there are studies that are still in the theoretical study stage and there are already those who have made them in the form of prototypes (but only showing how hydropower works, not yet to produce electricity independently) and no one has used Boyle's Flask as a turbine driving material in power plants. Based on the initial research conducted by the researcher by conducting interviews with teachers at junior high schools in North Bengkulu and teachers at UNRAM and UIN FAS Bengkulu, they agreed that they needed a prototype hydroelectric power plant that could be brought into the classroom. The same thing was also conveyed by prospective teachers at UIN FAS Bengkulu.

2. *Design*

   The design of the Boyle's Flask-based *hydropower plant PROTOTYPE* as a science teaching material is as follows:

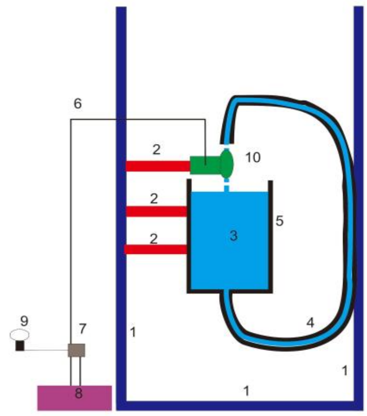

Figure 5: Product design to be developed

Information:

1= Supporting iron as the main frame;
2= Supporting iron as a support for dynamos and tubes;
3= The fluid that will rotate the turbine on the dynamo;
4 = The pipe that carries the liquid from the tube and back again to the tube. In this design, the pipe to be used is a 2.5 in plastic pipe;
5 = The tube as a place to store liquid with the diameter of the upper tube is 50cm and conical until it forms a lower diameter of 10cm;
6= Electrical cable to conduct electric current from the dynamo to the *Controller* then to the battery then to the lamp;
7= *Controller* to convert the current generated from the dynamo (AC current) into DC current so that electrical power can be stored in the battery. In this design, the researcher plans to use *a regulator rectifier* or shogun 125 Fd motor fan that can change AC current to DC and at the same time a means to be able to store electric current to the battery. In addition, the researcher will use a multimeter to measure the magnitude of the current generated from the dynamo;
8= Battery as a storage of power generated from the dynamo;
9= Lamp as an example of electrical output output;
10 = dynamo as a generator of electricity;

1. *Development*

Product development in the research is carried out in stages, namely:

1. The first stage of development is to make a prototype of a hydroelectric power plant based on *Boyle's Flask*. At this stage, the researcher plans to use a tube made of mica material to get the size of the tube to get the maximum output electrical power.
2. The second stage of development is to make tubes that have been made pre-made from aluminum plate material to make them more durable, then assemble them into a prototype of a hydroelectric power plant based *on Boyle's flask* and then measure the electrical power produced.
3. The fourth stage of development is to validate the prototype of a hydroelectric power plant based *on Boyle's flask* to material experts and media experts to assess its feasibility using validation guidelines that refer to the instruments used in Syifaul Fuada's research (Fuada 2015)

1. Implementation

The implementation stage is carried out by preparing learning tools. In this study, the implementation was carried out for students of the Tadris Science Study Program of UIN FAS Bengkulu who are taking basic physics courses and electrical and magnetism courses. The steps taken at this stage are: a. Preparing educators b. Preparing students c. evaluation

2. Evaluation

The evaluation stage in the research and development of the ADDIE model is carried out to provide feedback to product users, so that revisions are made according to the results of the evaluation or needs that cannot be met by the product. The final goal of the evaluation is to measure the achievement of development goals

Result and Discussion

The results of the research we conducted include:

1. Designing. The design of the prototype of a hydroelectric power plant based on *Boyle's Flask* as a science teaching material is as follows:

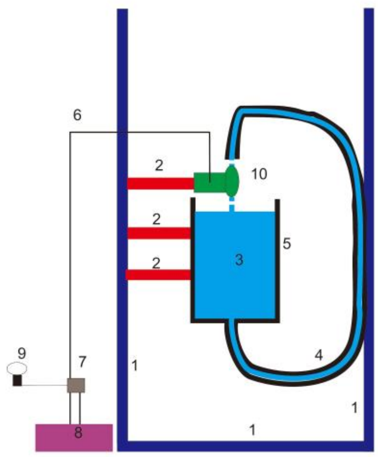

Figure 6: Product design to be developed

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5 = The tube as a place to store liquid with the diameter of the upper tube is 50cm and conical until it forms a lower diameter of 10cm;

6= Electrical cable to conduct electric current from the dynamo to the *Controller* then to the battery then to the lamp;

7= *Controller* to convert the current generated from the dynamo (AC current) into DC current so that electrical power can be stored in the battery. In this design, the researcher plans to use *a regulator rectifier* or shogun 125 Fd motor fan that can change AC current to DC and at the same time a means to be able to store electric current to the battery. In addition, the researcher will use a multimeter to measure the magnitude of the current generated from the dynamo;

8= Battery as a storage of power generated from the dynamo;

9= Lamp as an example of electrical output output;

10 = dynamo as a generator of electricity;

For simplification, the design of the tool has changed to:

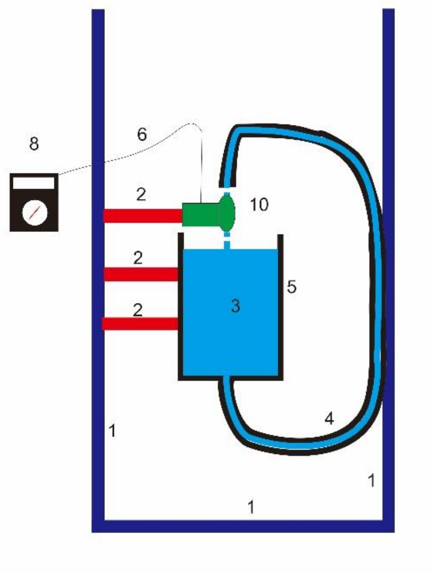

Figure 7: Simplified product design from the previous design

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2= Supporting iron as a support for dynamos and tubes;

3= The fluid that will rotate the turbine on the dynamo;

4 = The pipe that carries the liquid from the tube and back again to the tube. In this design, the pipe to be used is a 2.5 in plastic pipe;

5 = The tube as a place to store liquid with the diameter of the upper tube is 50cm and conical until it forms a lower diameter of 10cm;

6= Electrical cable to conduct electric current from the dynamo to the multimeter;

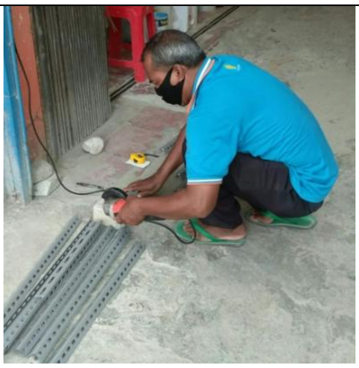
7= Multimeter to measure the strength of the current generated from the dynamo.

In this part of the design, the researcher eliminated the battery and the use of a fan and then replaced it with a multimeter because the researcher wanted to know the amount of strong electric current produced from this design.

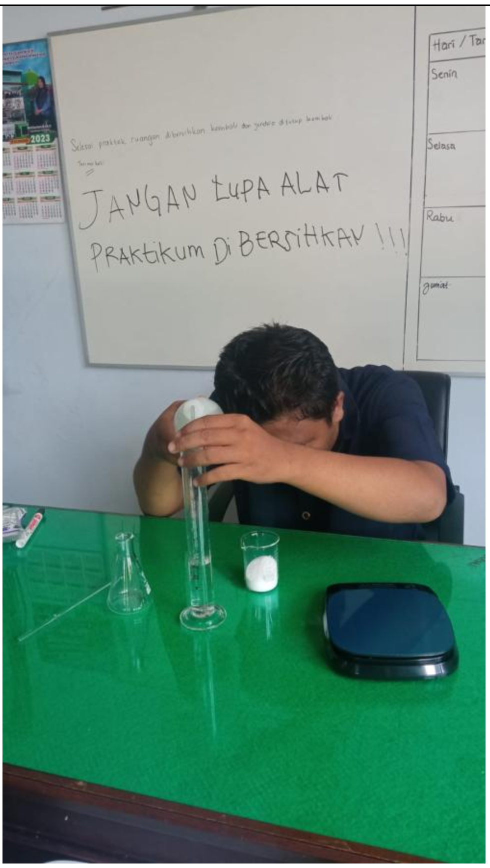
1. Realization

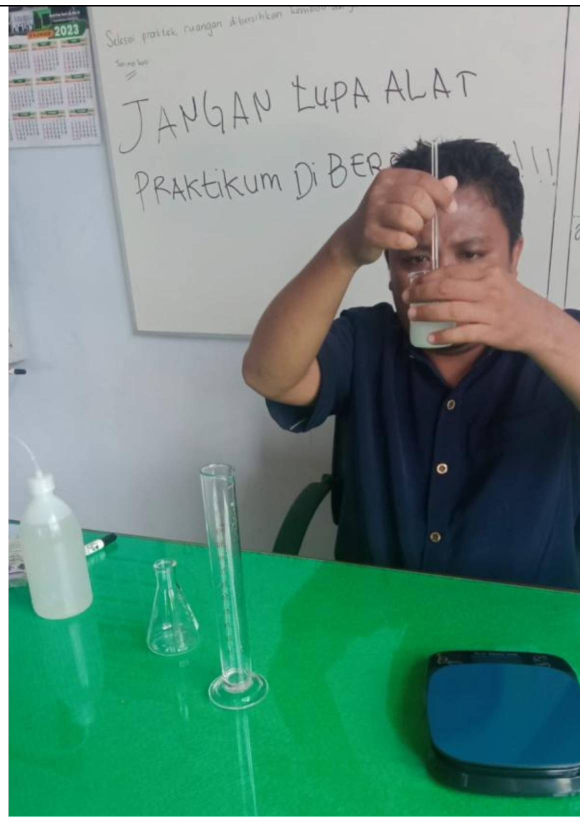
At this stage, there are several things that are done:

Table 1: the realization process of the design of a prototype hydroelectric power plant based on *Boyle's flask* as a science teaching material

Prosedur	Result
Asking a builder to make the main frame of a prototype hydroelectric power plant based on *Boyle's flask* as a teaching material for science	
Receiving the work of the craftsman	
Adjusting the work of the craftsman to the design (Cutting the water storage tube which we chose to use a gallon with a gallon volume capacity of 19 liters, has a diameter of 26.5 cm, a tubular height of 34 cm, a conical height of 15 cm and a filling hole diameter of 5.5 cm	

Filling the tube with water	
Testing a prototype of a hydroelectric power plant based on *Boyle's flask* as a science teaching material using a 2.5-inch pipe	
Testing a prototype of a hydroelectric power plant based on *Boyle's flask* as a science teaching material using a 0.25-inch pipe	

Calculate the density of the material to be added in the laboratory. The first step is to measure the mass of the object	
Calculate the density of the material to be added in the laboratory. The first step is to measure the mass of the object	

The third step is to mix the ingredients and water	
The fourth step is; Calculate the final volume (V1) and then calculate the magnitude of the density of the object using the equation: $$\rho = \frac{m}{V}$$	

Testing a prototype of a hydroelectric power plant based on *Boyle's flask* as a teaching material for science using a 0.25-inch pipe with a higher ρ of water	

In physics, water is included in the study of fluids which by definition is a substance that has the ability to change continuously when experiencing friction (having a reaction to the slightest shear stress). In addition to water, air is also a fluid but has a difference in its properties, namely having a free surface, the mass will fill the room according to its volume and is not compressed. While the gas has no free surface, its mass is always expanding, filling the entire volume of the room and can be compressed. Some of the quantities contained in the fluid include:

1. Density (density) and specific weight: Density is the mass per unit volume, while specific weight is the weight per unit volume.
2. Pressure: In this case, there is absolute pressure and there is also gauge pressure. The latter is none other than absolute pressure minus atmospheric pressure (1 atm). The pressure of a fluid is usually measured with a manometer (liquid) or barometer (gas).
3. Temperature (temperature), specific heat, thermal conductivity, and coefficient of thermal expansion: Specific heat is the amount of heat energy required to raise a unit of mass by one degree. Thermal conductivity indicates the ability of a fluid to conduct (conduct) heat. Meanwhile, the coefficient of thermal expansion connects temperature and density at constant pressure.
4. *Compressibility*: In this case, fluids can be divided into *compressible fluids* and *incompressible fluids*. In general, liquids are *incompressible* while gases are *compressible*. The ability of a fluid to be compressible is usually expressed in *bulk compressibility modulus*. The terms *compressible fluid* and *incompressible fluid* should be distinguished from the terms *compressible flow* and *incompressible flow*. *Compressible flow* is a flow in which the density of the fluid does not change in the flow field, such as water flow. While *incompressible flow* is a flow where the density of the fluid changes in the flow field, for example air flow.
5. Viscosity: indicates the resistance of one layer to sliding over another. Another definition of viscosity is associated with the presence or absence of shear. Thus, viscosity is directly related to the magnitude of friction and shear stress that occurs in fluid particles. In this case, fluids can be differentiated into viscous fluid and inviscid fluid (sometimes also called *nonviscous fluid* or *frictionless fluid*). Actually, all fluids must have a viscosity, no matter how small. However, when the viscosity is very small and negligible, it is usually assumed to be *an inviscid fluid*.

1. Surface tension: is the amount of tensile force acting on the surface of a fluid (liquid). Another definition is: the intensity of molecular attraction per unit length on any line of the fluid surface. The dimension of the surface tension is the force per length. An example of the effect of surface tension is, if a razor blade is placed slowly on the water, the razor blade will not sink due to the surface tension of the water.

The researcher examined the physical magnitude of the prototype of a hydroelectric power plant based on *Boyle's flask* as a science teaching material

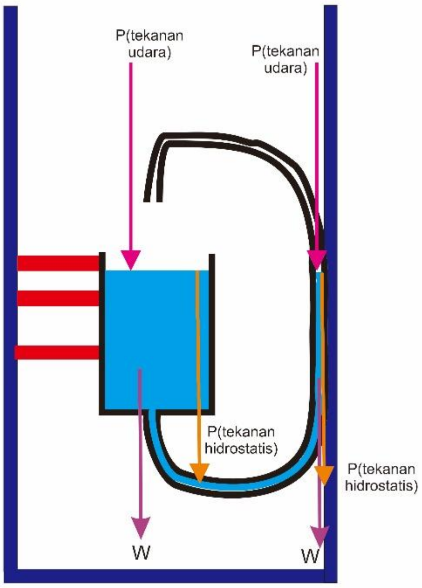


Figure 8: large-scale analysis of physics

As the researcher has described above, there are several quantities that affect the prototype of a hydroelectric power plant based on *Boyle's flask* as a science teaching material, namely hydrostatic pressure, air pressure and heavy force. Which is the equation is:

$$P = \rho . g . h$$

Which:
P = hydrostatic pressure (atm/pascal)
ρ = density of fluid (kilogram/meter^3)
g = acceleration of Earth's gravity (9.8 m/s^2)
h = depth (meters)
As for the weight force equation, it is:

$$W = m.g \qquad (2)$$

Which:
W = weight of the object (newtons)
m = mass (kg)
g = acceleration of Earth's gravity (9.8 m/s^2)

Another measure that needs to be studied is that the pressure is proportional to the force and inversely proportional to the surface area

$$P = \frac{F}{A} \qquad (3)$$

P = hydrostatic pressure (atm/pascal)
F = Gaya (Newton)
A= surface area (meters^2)

In the experimental stage, the prototype of a hydroelectric power plant based on *Boyle's flask* was tested as a teaching material for science using a 2.5-inch pipe. The researcher's hypothesis is as follows:
Assuming that there is a difference in surface area between the tube and the 2.5inch hose which will make the water rise because it meets the hypothesis
"The amount of water pressure in the tube is greater than in the 2.5-inch interval because the water surface area in the tube is larger than in the 2.5-inch tube".
Where:
Independent variable: surface area
Control variable = altitude, acceleration of gravity, depth of water, and acceleration of gravity
Bound variable = water pressure
However, based on experiments, it was found that:

Table 2: At 2.5-inch tube

On large tubes		At 2.5-inch tube
Air pressure + hydrostatic pressure + gravity	=	Air pressure + hydrostatic pressure + gravity

The water in the large tube has the same height as the water at 2.5 inches intervals. Although it was not as expected, this was a new discovery for researchers. With these results, the researcher changed the variables in the hose by using a 10-fold smaller hose, namely using a 0.25inch hose with a hypothesis
"The pressure of the water in the tube is greater than in the 2.5-inch interval because the surface area of the water in the tube is larger than in the 0.25-inch tube".
Where:
Independent variable = surface area
Control variable = altitude, acceleration of gravity, depth of water, and acceleration of gravity
Bound variable = water pressure
However, based on experiments, it was found that:

Table 3: analysis of physical quantities at 0.25-inch tube

On large tubes		At 0.25-inch tube
Air pressure + hydrostatic pressure + gravity	=	Air pressure + hydrostatic pressure + gravity

The water in the large tube has the same height as the water at 0.25 inches of hose. Although it was not as expected, this was a new discovery for researchers.
With the new discovery even though it was not in accordance with expectations, the researcher tried to find more information, one of which was through youtube and found several videos that succeeded in

making *a boyle flask*

Figure 9: screenshot of a video sourced :
https://www.youtube.com/watch?v=QE9wHXigokc

Figure 10: screenshot of a video sourced:
https://www.youtube.com/watch?v=9ASZzk8Dh-c

Figure 11: screenshot of a video sourced from
https://www.youtube.com/watch?v=CJ1Ko8W7iLk

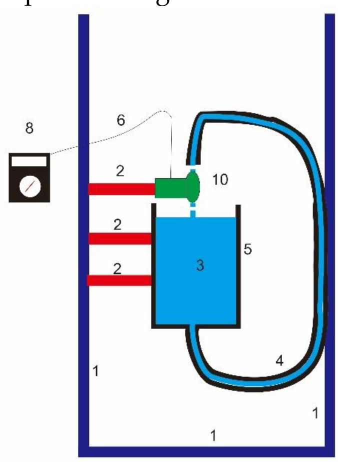
From several videos that researchers have studied, it turns out that no one uses pure water but uses liquids of different densities. The researcher tried to use a liquid substance with a different density by adding another material (in this case, salt) which the researcher assumed from the equation $P = \rho . g . h$ where the amount of pressure was proportional to the density, so the researcher tried to add another substance so that it changed the density and the hope was that it would increase the pressure in the large tube so that it would cause the pressure in the main tube to be higher and cause the water in the hose to be pushed but before the Applying it in the study, researchers conducted experiments in the laboratory to measure the magnitude of the salt density. The data was obtained that the density of salt was 2.17 kg/meter3.

Then the researchers mixed every 250 grams of salt into 19 liters of water in a gallon. At the addition of 250 salts, there was no change in the water level at the interval height of 0.25 inches. Then the researcher added 250 salts (500 grams in total), there was no change in the water level at the height of the 0.25 inches of hose. Then the researcher added 250 salts (750 grams in total), there was no change in the water level at the height of the 0.25-inch hose. Then the researcher added 250 salts (1000 grams in total), there was no change in the water level at the height of the 0.25 inches of hose. Then the researcher added 250 salts (1250 grams in total), there was no change in the water level at the height of the 0.25 inches of hose. Then the researcher added 250 salts (a total of 1500 grams), there was no change in the water level at the height of the 0.25 inches of hose. Then the researcher added 250 salts (a total of 1750 grams), there was no change in the water level at the interval height of 0.25 inches. Then the researcher added 250 salts (2000 grams in total), there was no change in the water level at the height of the 0.25 inches of hose. At this stage, the researcher stopped adding salt because there was no change in the height of the water hose. This is a new discovery in this study.

Conclusion

After conducting research, the researcher found that:

1. Boyle's Flask-based *hydropower plant prototype* development design.



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5 = The tube as a place to store liquid with the diameter of the upper tube is 50cm and conical until it forms a lower diameter of 10cm;

6= Electrical cable to conduct electric current from the dynamo to the multimeter;

7= Multimeter to measure the strength of the current generated from the dynamo.

As for the magnitude of the strong electric current generated from the prototype of the *Boyle's flask-based* hydroelectric power plant and the analysis of the relationship between the size of the prototype of *the Boyle's flask-based* hydroelectric power plant and the strength of the electric current produced, it cannot be done because the liquid substances are not water and salt water cannot flow endlessly even though there have been changes in several variables (using hoses measuring 2.5 inches and 0.25 inches, using water and salt water with different densities).

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