A Device For Electricity Generation Using Alternative Renewable Energy Sources

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Abstract: This study is devoted to developing a new method of electricity generation using an alternative source of renewable energy. It is obvious that day and night temperatures are different. This difference forces matter to expand and contract periodically. The forces arising from the everyday thermal expansion and contraction of solid and liquid materials can be considered such a source. Based on this phenomenon, the possibilities of creating an electricity-generating device are discussed hereon. Theoretically, it is possible to design a machine using solely solids or liquids, but this requires materials and high-volume vessels that can sustain extremely high pressures and mechanical loads and the accuracy of the details should be very high, which would lead to exorbitant costs. A combined model allowing a reduction in costs is discussed in this work. The constructional dimensions and the principle of functioning of a prototype that can produce 100 kWh are presented. The techniques explored to develop more powerful machines using this novel method are attractive in light of renewable sources of energy.

Keywords: Electricity generation; Power; Pressured vessels; Thermal contraction; Thermal expansion; Renewable energy.

INTRODUCTION

Human development depends on energy consumption. A major part of consuming energy is produced using natural fuel today. On the one hand, we are depleting natural resources, while on the other, we are devastating the ecology. The estimated share of renewable energy in global electricity production was 26.2% at the end of 2018 according to a report [1]. Existing renewable sources cannot be used everywhere and at all times due to the limitations of their origin and the principles on which their devices operate. Thus, a quest for new renewable sources of energy is encouraged. The scientists and professionals of the world have spectacular achievements in this respect. The young generation of our department is in the nascent stage of its development: the parameters of a solar panel have been estimated [2,3], the types of solar panels have been studied [4], the perspective of using solar energy has been discussed [5]and the optimal method of controlling hydroelectric power plants has been considered [6].The present research is devoted to developing a new method to produce electricity using an alternative source of renewable energy.

The preliminary considerations and related work are discussed in our previous works [7,8]. The method of producing electrical energy from thermal expansion and contraction of matter was patented in 2018 [9].

Huge forces can arise from the thermal expansion and contraction of liquid and solid matter: liquids can rupture or deform containers or vessels and solids can destroy bridges, buildings or rails if adequate preventive measures have not been implemented with foresight. Finding ways to use these enormous forces to produce useful energy is the aim of our investigation.When discussing thermal expansion, liquids show good promise.To begin with, the thermal expansion coefficients of liquids are dozens of times greater than those of solids. Moreover, volume expansion can be used in liquids, while it is difficult to do so in the case of solids. The work performed by liquid thermal expansion is expressed as follows:

$$W=P\Delta V, \quad (1)$$

where P is the pressure in the hermetically sealed reservoir and ΔV is the extra volume of the liquid arising from thermal expansion. Note that the thermal expansion of the vessel should also be taken into account. This will decrease the extruded volume, though insignificantly (Figure 1).

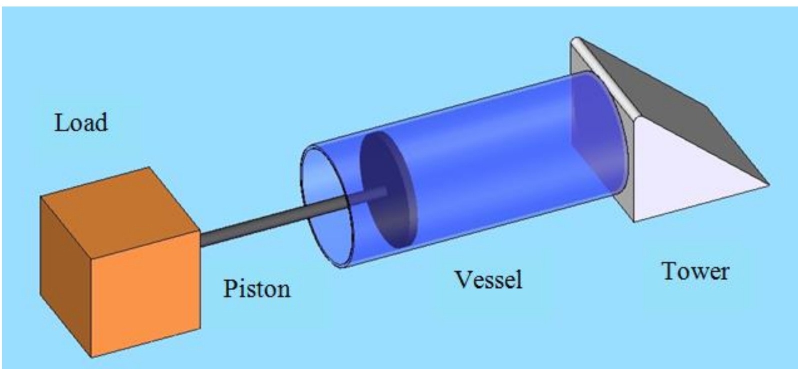

Figure 1.The work performed by the volume expansion of liquid.

As it is clear from Figure 1, the liquid will move the piston due to the excess volume from thermal expansion and, in turn, the piston performs some work in moving the load. Theoretically, any amount of work can be obtained by changing the mass of the load if we have a large enough initial volume of the liquid and a change in temperature. Note that the vessel should be able to sustain enough high pressure. Power can be defined as the work performed in time as follows:

$$Power=Work/Time \quad (2)$$

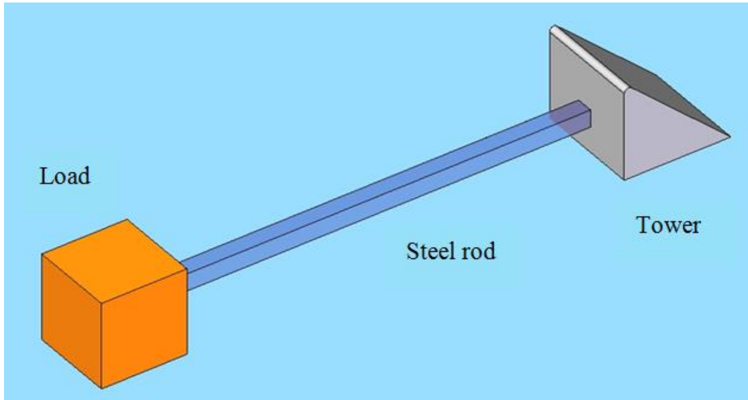

Figure 2. The work performed by the linear expansion of solids.

In the case of solids, as was mentioned above, linear expansion can be used solely to produce the energy. A long metal rod, one end of which is fixed and motionless, will elongate with the rise in temperature and drive the load (Figure 2). The work performed by the thermal expansion of a steel rod can be expressed as follows:

$$W=F\Delta l \qquad (3)$$

where F is the force due to the linear expansion of the steel rod and Δl is the displacement of the load. In this case as well, we can obtain any amount of work by changing the mass of the load.

MATERIALS AND METHODS

a. Use of liquid expansion

If we design the devices to generate electrical energy of 10, 100 and 1000 kWh using the thermal expansion of liquid (Figure 1), they should perform work of $3.6\cdot10^7$, $3.6\cdot10^8$ and $3.6\cdot10^9$J per hour, respectively. Let the losses not be taken into account for the first approach and let us suppose that the work obtained according to Equation (1) is wholly transformed into useful energy. The excess of volume ΔV can be computed asfollows [10]:

$$\Delta V=V_0\beta\Delta T, \qquad (4)$$

where V_0 is the initial volume of the liquid, β is the coefficient of volume expansion and ΔT is the change in temperature. Now, Equation (1) can be written as follows:

$$W=PV_0\beta\Delta T \qquad (5)$$

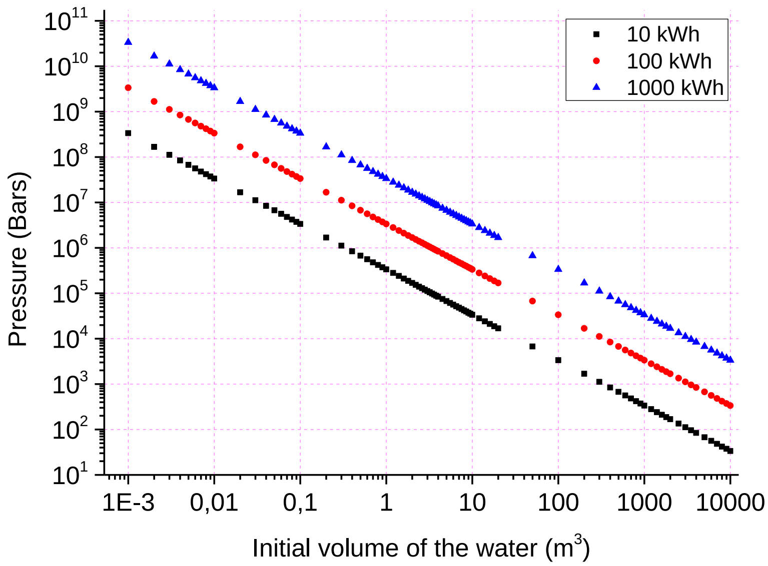

Figure 3.Relations between the pressure and the initial volume ofthe liquid for devices of 10, 100 and 1000 kWh.

Figure 3 shows the relationship between the pressure and the initial volume of the liquid in the cylinder for the devices of 10, 100 and 1000 kWh power.The pressure is calculated using Equation (5) for the initial volume of the working liquid from 10^{-3} to 10^4m^3. Pure water is chosen as the working liquid, the volume expansion coefficient of which is $\beta=2.14\cdot10^{-4}$ $^{o}C^{-1}$ [11]. The temperature change, ΔT, is 50 ^{o}C. Note the following assumption: the temperature changes linearly in 10 hours; the work is also calculated in 10 hours. As is seen from the figure, the device for 10 kWh with a volume 10^{-3}m^3 of water requires the pressure to be held by the vessel to be almost $3.365\cdot10^8$ bar ($3.365\cdot10^{13}$ Pa). The pressure decreases with an increase in the initial volume of water. If the initial volume increases up to 100 m^3, the pressure is about $3.365\cdot10^3$ bar ($3.365\cdot10^8$Pa). In the case of the devices for 100 and 1000 kWh for the same initial volume of water, the pressures are 10 and 100 times more, respectively. Setting up vessels with such volume to hold the stated pressures is not feasible while considering the recovery of costs. Moreover, it was experimentally determined in our previous work that liquid works well in expansion, but its performance is less than desirable in the contraction process owing to the weak attractive forces between atoms[8].

b. Use of solid expansion

The work done is expressed by Equation (3). With a rise in the temperature of the steel rod,the force acting on the load begins to increase (Figure 2). When it reaches a certain value called the breakaway force [12], the load starts to move. The speed of the load is very less and it depends on the rate of temperature change. The character of this driving force is that it can provide enough large value depending on the mass of the load. In other words, one can choose any value of the force by changing the mass of the load. Although the distance Δl is very small, the force F can reach high enough values and we can obtain any amount of work desired.The linear expansion of solid material, Δl, is defined as follows [10]:

$$\Delta l=\alpha L_0 \Delta T\ , \qquad (6)$$

where $\alpha=12\cdot10^{-6}\ {}^{o}C^{-1}$ is the linear expansion coefficient of steel, L_0 is the initial length of the steel rod and ΔT is the change in temperature. Now, Equation (3) can be written as follows:

$$W=F\alpha L_0 \Delta T. \qquad (7)$$

A steel rod with an initial length of 50 meters expands 0.03 meters when the change in temperature, ΔT, is 50 ^{o}C according to Equation (6).The compressive yield strength of steel is 152 MPa ($152\cdot10^{6}$ Pa) [13]. If we take into account that it is defined as [14] σ =Load/Area(kg/mm^2), it can be found that the force acting on the 1 mm^2 area corresponding to the compressive yield strength of steel is $F=152kg=1.491\cdot10^{3}$ N. Considering that the forces due to thermal expansion will act on an area much larger than 1 mm^2, the expected compressive strength will certainly be appreciably smaller than the compressive yield strength of steel. In other words, the steel rod will not be bent or deformed by the expansion force in our case. The main problem is how to accelerate the slow motion of the end of the steel rod by thermal expansion: the load will shift 0.03 meters in10 hours. The device that can solve this problem is suggested in this work.

RESULTS AND DISCUSSION

The computer-aided design (CAD) of the device presented in Figure 4 consists of towers (1), a steel rod (2), lever system (3), piston (4) for shifting high pressured liquid, high-pressured vessel (5) filled with working liquid, two-side piston (6), low-pressure vessel (7), also filled with the working liquid,transducer (8), gear train (9), generator (10), free-moving piston (11) and reservoir for working liquid (12). In principle, the device can be designed for any amount of power. Here, we decided to design the device for 100 kWh. It can be cost effective in supporting the electricity needs of small farms and plants as well as populations in remote places, providing electricity to distant locations related to valuable power lines and heavy losses.

The dimensions of the device are calculated in the following way. As assumed, the temperature of the steel rod (2) changes by 50^{o}C and the free end of the steel rod (2) moves 0.03m in10 hours. Due to the first-class lever system, the distance increases by 10 times and the piston (4) moves 0.3 m. The work performed in the high-pressured vessel (5) can be expressed as follows:

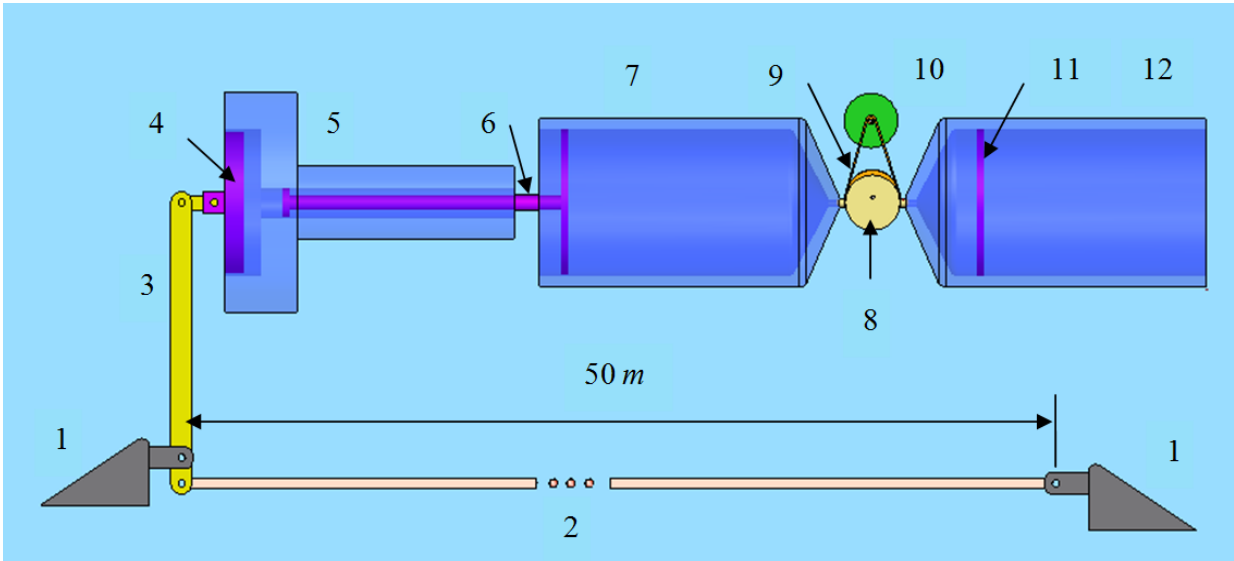

Figure 4. CAD of the device. 1 – towers, 2 – steel rod, 3 – first-class lever system, 4 – high-pressure piston, 5 – high–pressuredvessel, 6 – two-side piston, 7 – low-pressure cylinder, 8 – transducer, 9 – gear train, 10 – generator, 11 – free-moving piston, and 12 – reservoir.

$$W=P_1V_1 , \quad (8)$$

where P_1 is the pressure of the working liquid created in the pressured vessel (5) by moving the piston (4) and V_1 is the volume of the working liquid extruded from the vessel through its output. These parameters can be utilized for a generator of any power by changing the dimensions of the pressured vessel (5). In our case, the extruded volume,$V_1=3.76991m^3$,is defined as follows:

$$V_1=\pi(r_{1input})^2\cdot l_{1input} , \quad (9)$$

where $r_{1input}=2.0$ m is the radius of the vessel (5) at the input and $l_{1input}=0.3$ m is the displacement of the piston (4). The pressure, P_1computed using Equation (8) for the 100kWh generator ($W=3.6\cdot10^9$J for10 hours) is approximately 954.93MPa ($954.93\cdot10^6$Pa). The vessel (5) and the piston (4) should be able to hold such pressure. The dependence of the pressure (for different powers) and volume of the working liquid on the input radius of the vessel (5) is presented in Figure 5. The pressure can be decreased by increasing the radius at the input but this will lead to an increase in the volume of the working liquid. For example, increasing the input radius twice decreases the pressure four times and increases the volume of the working liquid four times.

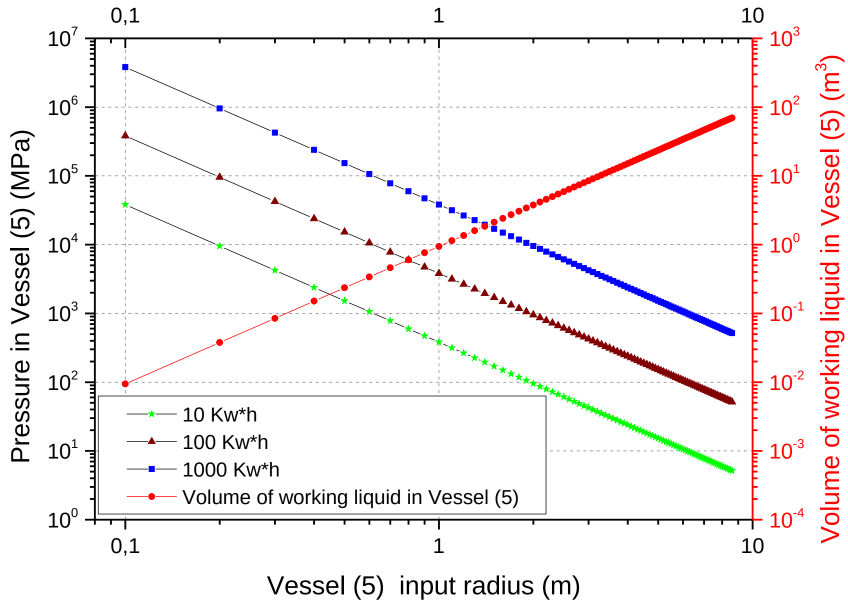

Figure 5. Dependence of the pressure (for different powers) and volume of the working liquid on the input radius of the vessel (5).

To calculate the diameter of the right side of the two-side piston (6),we choose the pressure P_2 in the low-pressure cylinder (7) 40Mpa ($40 \cdot 10^6$Pa), at which normal working conditions for the transducer (8) can be provided. Then, the volume of the working liquid in the low-pressure cylinder (7), $V_2=90\ m^3$,is calculated as follows:

$$W=P_2V_2\,, \qquad (10)$$

where P_2 is the pressure in the low-pressure cylinder (7). Now, we can find the inner diameter of the cylinder (7), which is equal to the diameter of the right side of the two-side piston (6), $r_2=2.023$ m,using the following:

$$V_2=\pi r_2^2 l_2\,, \qquad (11)$$

where $l_2=7$m is the chosen length of the cylinder (7). Note that the equality of the lengths of the reservoir (12) and output side of the high-pressure vessel (5) to this size makes it easier to adjust these parts of the device. Now, we can define the output radius of the high-pressure vessel (5),$r_{1output}=0.414$ m, from the following Equation:

$$V_1=\pi\ (r_{1output})^2 \cdot l_2. \qquad (12)$$

Usually, the temperature in the environment starts to rise early in the morning until midday, and then it ceases to rise and after a while, begins to fall. This fall in temperature will continue until midnight. The device works in the following way.The steel rod (2), one end of which is fixed and motionless at the tower (1), will provide the device with driving force. As the temperature of the environment starts to rise, the steel rod (2) starts to elongate, acting on the piston (4), which begins to move when the force reaches the breakaway value. The first-class lever system will increase the distance by 10 times and due to this, we will decrease the pressure by 10 times in the high-pressure vessel (5). Note that the mechanical resistance of the generator depends on its power. The power of our generator is 100kWh and for the first approximation, we neglect all other friction losses. Then the breakaway force is defined by the power of the generator alone. The piston (4) creates pressure in the vessel (5). The pressure will increase until the liquid starts to displace the two-side piston (6) and after that, it remains almost constant. This is the working pressure of the vessel. Due to the small outlet radius of the vessel (5) compared to the inlet one, the two-side piston (6) will move a noticeable distance and drive the liquid from the low-pressure vessel (7) to the transducer (8). The latter, acting as a positive displacement flowmeter, will transform the linear motion of the liquid into circular motion and transmit to the generator (10) through the gear train (9). The generator (10) then starts to produce electricity. The working liquid, passed through the transducer (8), pushes the free-moving piston (11) and gathers in the reservoir (12). The process will stop when the temperature of the steel rod reaches the maximum level. After 10 hours, when the temperature starts to decrease, the backward process begins: the steel rod (2) starts to shrink, pulling the piston (4) backward through the lever system (3). The piston (4) creates the vacuum in the vessel (5). The vacuum pulls the two-side piston (6). The working liquid from the reservoir (12) returns to the low-pressure vessel (7) through the transducer (8). The transducer transforms the linear motion of the liquid into circular motion and transmits to the generator (10) through the gear train (9).

The working liquid in the high-pressure vessel (5) and low-pressure cylinder (7) performs additional work by thermal expansion and provides extra power. The approximate value of the total work of the liquid for our device for10 hours, $3.0816 \cdot 10^7$J, is calculated as follows:

$$W_t = P_1 \cdot \Delta V_1 + P_2 \cdot \Delta V_2 , \qquad (13)$$

where $\Delta V_1$and ΔV_2 are the excess volumes of the water in the high-pressure vessel (5) and low-pressure cylinder (7) due to thermal expansion, which are defined by equations similar to Equation (4). The temperature change across10 hours, ΔT, is assumed as 20 ^{o}C. This work is less than 1% compared to the work of the 100 kWh device. It will increase if the temperature change ΔT increases. Another way to obtain more work is to choose the working liquid with a higher thermal expansion coefficient. Such a supplementary power can help compensate for the losses and increase the efficiency of the device.

CONCLUSIONS

The possibility of generating electrical energy from the thermal expansion of liquid and solid matter is considered. Setting up the device using solely the liquid thermal expansion and contraction phenomena requires high-volume vessels that shouldbe able to sustain very high pressures, which is expensive and difficult to realize. In the case of using the thermal expansion and contraction of only solid material, the problems will include their small coefficients of thermal expansion compared to liquids, the impossibility of using the volume expansion, and very slow displacement velocity, which is difficult to accelerate.If both liquid and solid materials are used in combination, one can find reliable and cost-effective compromise variants of the device for different magnitudes of power.

The principle of the working of the device, designed using both solid and liquid materials, is presented. The small but powerful displacement will be transformed into high pressure and this pressure is transformed into liquid flow through the transducer. The latter transforms the flow into a circular motion and transfers this to the generator, which produces the electricity.

The new type of device, which uses a renewable energy source, requires high pressure vessels. The pressure in the vessel (5) can be reduced by increasing its diameter: if the radius r_{1input} increases twice, the pressure P_1decreases four times. On the other hand, decreasing the pressure leads to the increased volume of the working liquid, which is related to energy losses.

As the processes of thermal expansion and contraction are very slow, transforming them into fast enough linear or circular motion requires modern and very accurate techniques. It is important to find the optimal and compromise values of multiple operating parameters, such as the length of the steel rod, the pressures in the vessel (5) and in the low-pressure cylinder, the diameters of the vessels, the volume of working liquid, the flow rate, and the speed of angular velocity of the shaft of the generator in creating the new type of renewable energy source. However, such a complex task can be simplified noticeably if we develop the high-pressure and high-volume cylinders: the power of the device is in direct proportion to the pressure, which can be sustained by the system. So, by increasing the pressures in the vessel (5) and cylinder (7) by 10 times, the same device can generate 1000 kW energy per hour in our case.

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