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Lifting Water by Means of Air Cushion

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Abstract: ***Lifting water to higher altitudes without using any external energy has been the target for many scientists and engineers. Hydraulic rams and hydraulic turbines are some examples. This work is a contribution to those efforts, in which potential energy of a water source is converted into pressure energy in a closed down stream air chamber. The pressure energy obtained is transferred to an upstream lifting water tank in order to push the water to higher elevations. A laboratory model is built to study this idea. Results obtained were promising. The method is simple and could have field applications at locations where rivers and streams undergo sharp changes in their bed slopes.***

Keywords: Lifting water, Air cushion, Renewable Energy, Potential energy, Pressure energy, Boyle's law

1. Introduction

After the industrial revolution, the wide spread use of fossil fuels like petroleum, coal, etc. caused disastrous environmental problems. The use of renewable or clean energy for human activities becomes more popular day after day. Wind mills, water mills and hydraulic rams have been used for many centuries to lift water to higher locations. In all those methods kinetic energy or the impact force of flowing water is converted into mechanical or pressure energy (in the case of hydraulic ram)(KHURMI,1998). In this work a simple method is used in which a fraction of the potential energy of the water source is brought down to a lower convenient level downstream of the source and used to pressurise air in a closed air chamber. This pressurized air cushion is transferred through a pipe up to a previously filled water tank to push the water to higher altitudes.

2. Theory

The potential energy of a liquid is defined as the energy possessed by a liquid particle by the virtue of its position(1). If a liquid particle is **z** meters above a horizontal datum (arbitrary chosen) then the potential energy of the particle will be **Z**(m.kg)per kg of the liquid. Then a mass of water of **W**(kg) of water at a height of **Z**(m) from a datum has a potential energy of **WZ**(m.kg).

If a fraction of this mass **ω** is brought down to the datum level then the potential energy of the source water is decreased by an amount equal to **ωZ**(kg-m). According to the law of conservation of energy this decrease in the potential energy could be converted into an increase in the internal energy of air in a closed chamber, i.e.:

$$\omega Z = \Delta Ep \ldots.. \qquad (1)$$

Where,

ΔEp is the increase in the internal energy of the cushion. As the air density is negligible compared with the density of water, then, **ΔEp** would be able to push **ω** kg of water to height **Z** above the water source level theoretically. In practice the amount of **ΔEp** applied at the source level would be less than (**ωZ**) due to frictional losses in the pipings and other possible minor losses.

3. Laboratory Model

A schematic diagram of the laboratory model is shown in figure (1)which consists of:

1. Source tank which represents the water source and has a cubical shape of side length of 1 m and a volume of $1m^3$.
2. Delivery tank which has a cylindrical shape of height of 0.8 m and diameter of 0.45m (volume = $0.127m^3$) this tank is completely sealed and a pipe of 1.5 cm diameter goes down through it reaching to about 1 cm above its bottom. This is the delivery pipe through which water is lifted.
3. The air chamber which has a cylindrical shape and laid at a level of 7m lower than the source and the lifting tanks. The air chamber has the dimensions of 90cm height and 60 cm diameter (volume $0.25m^3$). The three tanks are connected together using 1.5 cm plastic pipe with a numbers of valves and a pressure gauge as shown in figure (1).

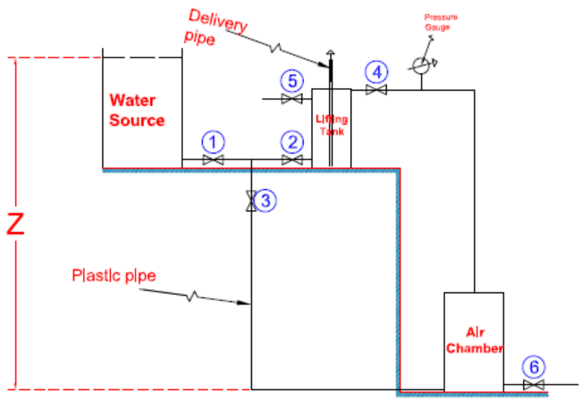

Figure 1: "Schematic diagram of the laboratory model"

4. Test Procedure

The following steps are followed to operate the model:

1. With all the valves closed except valves 1, 2, and 5 the lifting tank is filled with water. The water is supplied from the source tank.

2. Valves 5 and 2 are closed and valve 3 is opened letting water to flow from the source tank into the air chamber, under the effect of gravity. The air in the chamber is compressed gradually and its pressure is observed through the pressure gauge. Pressure reaches its maximum value when the pressure gauge reads the value of the head **Z**.
3. Valve 4 is opened thus connecting the pressurised air cushion to the top surface of the water in the lifting tank causing water to flow to higher altitude through the delivery pipe.
4. This process is continued until the air cushion is exhausted, the air chamber is filled with water and water ceases to flow. This is the end of the delivery cycle.
5. To start a new delivery cycle valves 5 and 6 are opened the air chamber is drained from the water which accumulated during the delivery cycle, and the whole procedure is repeated.

5. Results

For the model sizes and specifications mentioned previously, the model was able to lift **80 litres** of water during **17 minutes** to an evaluation of **3m** above the lifting tank. This means an average rate of lifting of **4.7 L/min**.

6. Discussion

It was observed that the rate of lifting water was not constant during the test with maximum rate of 2*4.7 = **9.4 L/min** at the beginning. The rate at which water lifted depends mainly on the height **Z** and the height to which water is lifted. As the pressure of the air cushion was exhausted gradually the rate at which water was lifted, decreased and approached zero at the end of the delivery cycle.

Field Application

This method is applicable where rivers or streams undergo sharp increase in their bed slopes which means large difference between the source and the air tank elevationswithin a short horizontal distance. The method is not continuous i.e. water is not lifted while the air chamber is drained from the water and re-pressurised. This is not desirable in practice. This problem could be solved by using two sets of air chambers and lifting tanks. While one set of these tanks are used for lifting, the other set is used to pressurise the air chamber. Thus a semi continues process could be obtained.

7. Design Calculations for the Air Chamber Volume

The size of the lifting tank is the same as the volume of water to be lifted in one cycle. The size of the air chamber is related to the size of the lifting tank and the available head which could be calculated in the following way:

If $\mathbf{V_L}$ is the volume of water to be lifted in one cycle,then the minimum volume oh pressurised air cushion should equal to $\mathbf{V_L}$.

If $\mathbf{V_a}$ is the volume of air chamber and applying Boyle's law on a head basis, instead of pressure:

$$\mathbf{H_1V_1 = H_2V_2} \qquad \text{.........} \ (2)$$

Where; $\mathbf{H_1}$ is the initial head of the air chamber which is equal to atmospheric head of**10.33 m** water and $\mathbf{H_2}$ is the final head of the air chamber which is equal to (**10.33 + Z**) **m** of water. Substituting these values in eq. (**2**)

$$\mathbf{(10.33) \times V_a = (10.33 + Z) \times V_L}$$

$$V_a = \frac{(10.33+Z)V_L}{10.33}$$

As an example if $\mathbf{V_L = 0.127\ m^3}$ and **Z= 7 m**

Then,

$$Va = \frac{(10.33+7) \times 0.127}{10.33} = 0.213m^3$$

This is consistent with the model air chamber volume.

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