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Development of Mechanical Water Level Controller

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***Abstract* - The automatic water level controller is a device designed to regulate automatically the pumping of water to an overhead tank without allowing the water in the tank to be exhausted. The design of this mechanical device was achieved using the Archimedes principle of floatation; having a float which determines the water level in the tank depending on the choice of the minimum (lower) and maximum (upper) level inscribed in the tank. The fundamental attribute of this device is the ease in design, fabrication and mounting at a lower cost. Its testing had shown and proved that it works efficiently with Archimedes' principle of floatation. This eliminates the frequent human intervention/monitoring of the water level in the overhead tank to control overflow manually, thereby eliminating water and energy wastages.**

***Keyword* - automatic, controller, floatation, overflow, mechanical, overhead tank.**

I. Introduction

It is common to see water overflow from overhead tanks after it has been filled by the installed submersible pump in the borehole or reservoir. This results in wastage of both water and electrical energy. It is against this background that this project originated. It is necessary to efficiently use our water resources to save cost and power. The Automatic Water Level detector is a mechanical device that controls a mechanical switch which activates the submersible pump when desired with the aid of a floater. The switching action controls two predetermined levels: the minimum (lower) and maximum (upper) level. It cuts power from sumo-pump equipment when appreciable water level in the tank is attained and connects power to it when a certain low level of water is reached thereby using energy and water efficiently.

It can be adapted for modern houses (individual or corporate) apartments, commercial complexes, Hotels, Hospitals, Factories and other places wherever automation is required for controlling pump units. This would invariably prolong motor life. It serves 24 hours Water supply without letting the overhead tank to become dry.

II. Methodology

Design Development and Considerations.

The availability of the materials chosen for the design and cost was of primary consideration. They were chosen on the basis of properties such as strength, reliability, thermal considerations, corrosion, wear resistance, safety, weight, shape and size, surface finish, cost of production, Human factor, serviceability, and maintenance.

Principles and Analysis

The mechanical water level controller works with ARCHIMEDES' PRINCIPLES OF FLOATATION. The principle states that ***an object will float in a fluid (liquid or gas) when the upthrust exerted upon it by the fluid in which it floats equals the weight of the object.*** The buoyancy or upthrust acting on the object due to water must exactly counteract the weight of the object, i.e. the two have equal magnitude.

For floatation,

$$W = U \qquad (1)$$

Where,

W = weight of an object (or floater) (N),

U= upthrust of water on the float (N).

If the upthrust equals the weight of the object (floater) before the object is completely immersed, then the object will not sink but will float in the liquid (water).

$$U_{(force)} = V_{solid} \times p_{\ liquid} \times g \quad (2)$$

So, a partially immersed object floats in a liquid when the buoyancy acting on it equals the weight of the object.

$$U_{(force)} = V/3_{\ solid} \times p_{\ liquid} \times g \qquad (3)$$

Where $U_{(force)}$ =up thrust (buoyancy) of water on the float (N),

p = density of the liquid(water) (kg/m^3),

g = gravitational force(N).

An equivalent and useful criterion for flotation of any object is that it will float in a liquid, if the density of the object is less than that of the liquid. This is true, for example, for wood or ice, both of which have a lower density than water. A solid piece of iron or steel sinks in water because the density of iron is greater than that of water.

However, a thin walled**, hollow** cylinder of steel float was used for this work, with adequate volume of air trapped in it. This floats in water.

III. Material Selection

The materials used for this device were locally sourced. Material selection and chemistry component were done using data available according to NAFDAC, SON and WHO specifications. Food grade materials were selected for materials that are in direct contact with water. This is to encourage our local content advocacy as well as for better efficiency, ease of operation, maintainability and affordability by any class of individuals. The device is a simple unit that basically consists of the following components;

1. Spring-loaded pulley
2. Shaft
3. Floater
4. String
5. Mechanical switch

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The arrangement is as follows:

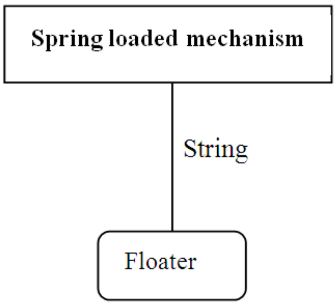

Fig.1. Block diagram of Device

The tension experienced by the string is dependent on the difference between the weight of the float and up thrust force of water.

$T_{(force)} = W - U$ (4)

Where $T_{(force)}$ = tension in string and spring (N),
W = weight of an object (float) (N),
U = upthrust of water on the float (N).

Equation (4) was used to determine the material, type of string and the spring constant.

Fig.2. Test rig with assembled device. (AWLC device arrowed)

Material selection such as plumbing fixtures and other equipment were done against scaling, corrosion, and staining because of the widely varying conditions and the many types of water,

IV. Spring Design Considerations

The fundamental mechanical components which form the basis of this work is the spring made of flat strips. The graph below shows the relationship between the elongation of the spring and the weight applied to the spring causing it to uncoil.

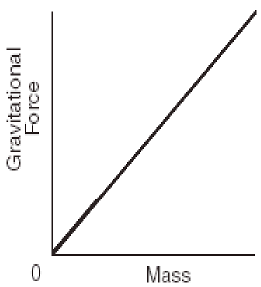

Fig.3. Graph showing elongation and weight relationship.

Assumptions:

$F = kx$ (5)

With x being the elongation and k the spring constant. So $x = (1/k)F$ or elongation (y) = (1/k).force (x). The recoiling of the spring is aided with the buoyancy effect of the liquid. Consideration of height of proposed overhead tank and length of string also play an important role in the design.

Power Spring

Power spring also known as clock, motor, or flat spring are made of flat strip material which is wound on an arbor and confined in a case. Power spring store and release rotational energy through either the arbor or the case in which they are retained. They are unique among spring types in that they are almost stored in a case or housing while unloaded. Figure below shows typical principle used in the design.

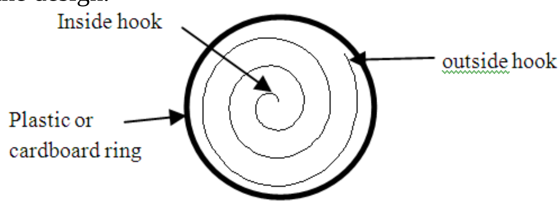

Fig.4. Showing spring arrangement

Power spring are stress in bending and is related to torque by

$S = \frac{6M}{bt^2}$ (6)

Like this work, load-deflection curve for power spring are difficult to predict. As a spring is wound up, material is wound onto the arbor. This material is drawn from that which was at rest against the case. Thus the length of active material is constantly changing, which make it difficult to develop a workable expression for the spring rate. For these reason, ratio, table and graphical presentations were used to develop the design criteria for this work.

The ratio of the arbor diameter to the thickness is the life factor. If it is too small, fatigue life will suffer. The life factor 15 is chosen. The ratio of active strip length to thickness was used to determine the flatness of the spring-gradient torque-revolution curve. The curve is flatter when length is longer. The ratio of the inside diameter cup (casing or housing) to thickness D_c/t to the turn factor determines the motion capability of the spring or indicate how much space is available between the arbor and the material lying against the inside of the case.In order to design a power spring that will deliver a given torque and number of turns, first determine the maximum torque in fully wound condition.

V. Operational Description

A test rig was installed to test the device as shown in the figure. The operational steps in the assembly list of instructions were taken thus;

a) The device (entire system) was mounted on top of the over-head tank.

b) The actuating knob triggered the switch to ON the pump when minimum (lower) level was reached.
c) With the aid of the floater system working in principle with recoil spring, when the level of water gets to the maximum (upper) level, the pumping of water was stopped automatically by the actuating switch.

VI. Conclusion

The device presented here has advantage over the existing ones. The materials used for the probes have effect on water as it is consumed due to electrolysis. Whereas the materials used for this device were made of food grade according to NAFDAC, WHO and SON specifications.

The automatic mechanical water level controller is a device that can be used to manage our water from wastage by any class of individual in our society.

Automatic mechanical water level controller saves the energy we expend in switching ON and OFF of our water pump.

The design is useful in water treatment facilities with appropriate feasibility studies and considering all engineering, economic, energy and environmental factors.

The use of this cheap technology should be encouraged and sustained in this time of scarcity of water in so many places. So, I recommend the supply of this device to those who cannot afford it, and encourage those who can afford it to go for this device in order to save water and energy for other works.

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