**Torricelli’s Experiment in case of glycerine and water : A Critical Analysis.**

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**Abstract**

The pioneering experiment regarding measurement of pressure was conducted by Torricelli (1608-1647) in 1644. But real theoretical understanding of the phenomena began after 1685, when Newton defined acceleration due to gravity g. Mathematically, pressure \( P = \rho gh \) is only dependent on density of fluid, and independent of other characteristics. The height of a mercury column in a barometer is 0.76m. If the water and glycerine barometers are constructed, then the height of water column must be 13.33m and that of the glycerine column is 8.202m. In the existing literature there are no quantitative observations that heights of liquid (water and glycerine) columns are confirmed quantitatively. If these predictions are precisely justified then these experiments can serve as an alternate method for measurement of g \( (P/Dh) \). The proposed experiments will be very significant in understanding the phenomena, in case even slight deviations are confirmed.

**1.0 Introduction**

The concept of pressure exerted by fluids can be understood in two phases i.e. before and after enunciation of the law of gravitation [1-3]. The first phase is the pre-gravitational period (before 1685) when basic and pioneering experiments regarding measurement of pressure were conducted without the mathematical basis. Italian scientist Evangelista Torricelli (1608-1647) constructed a mercury barometer, consisting of a long tube (about 1m) filled with mercury and inverted in a dish of mercury. In this simple barometer, the mercury column is held up to 0.76m. The original aim of Torricelli’s pioneering investigation (1643) may not have been to measure or invent a method for measurement of pressure [1,2].
The mathematical equation for measurement of pressure became feasible after 1685 when acceleration due to gravity $g$ was defined. Now pressure is given by

$$P = Dgh$$  \hspace{1cm} (1)

where $D$ is density of liquid and $h$ is height of liquid column.

French scientist Blaise Pascal (1623-1662) also believed to have constructed a barometer using red wine [2] and glass tube 46 feet long (about 12 m). But details are not available, on how Pascal estimated the height of red wine barometers. At that time, there was no mathematical equation to estimate height. In this regard, a German experimentalist Otto Van Guericke (1602 – 1686) known for Magdeburg hemispheres and the vacuum pump, is also believed to have constructed a water barometer. At that time, there was no mathematical equation to determine the height of the columns of red wine and water. If such equations are not confirmed quantitatively then reasons have to be investigated for the deviations. Thus such experiments are very-2 significant. Obviously, the mathematical equation for pressure i.e. $P = Dgh$, became feasible in 1685. So Torecili’s approaches may be regarded as pioneering but qualitative only as far as measurement of pressure is concerned.

1.1 A Critical Analysis Of $P = Dgh$

The unit of pressure, the Pascal was defined by simply putting the value of $h$ equal to 0.76m. In case of mercury ($h=0.76m$). Eq.(1) becomes

$$P = 13,600 \text{kgm}^{-3} \times 9.8 \text{ms}^{-2} \times 0.76 \text{m} = 1.013 \times 10^5 \text{ Pascal}$$  \hspace{1cm} (2)

Thus, according to eq.(1), pressure $P$ only depends upon the density of fluid, and is independent of all other characteristics of fluids i.e. co-efficient of viscosity, surface tension and angle of contact. It may also depend upon capillarity i.e., rise or fall of liquid in a tube of fine bore (diameter of a few mm). Now it has to be confirmed whether these factors affect the height of a liquid column in barometers. These characteristics are clearly independent of density and for comparison, the various characteristics of water, glycerine and mercury are shown in Table 1.

Table 1: Comparison of various characteristics of water, glycerine and mercury.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Water</th>
<th>Glycerine</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1</td>
<td>1.26</td>
<td>13.6 gm/cc</td>
</tr>
<tr>
<td>Coeff. Of viscosity (poise)</td>
<td>$1.01 \times 10^{-2}$</td>
<td>10.69</td>
<td>$15.5 \times 10^{-3}$</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------------</td>
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<td>----------------------</td>
</tr>
<tr>
<td>Surface tension</td>
<td>75.6</td>
<td>63.1</td>
<td>465 (dyne/cm)</td>
</tr>
<tr>
<td>Angle of contact</td>
<td>8-9°</td>
<td>--</td>
<td>137</td>
</tr>
<tr>
<td>Capillarity</td>
<td>Rise</td>
<td>--</td>
<td>Fall</td>
</tr>
<tr>
<td>Physical behaviour</td>
<td>Wets</td>
<td>Wets</td>
<td>Does not Wet</td>
</tr>
<tr>
<td>Height of liquid column (h)</td>
<td>10.33</td>
<td>8.202m</td>
<td>0.76m</td>
</tr>
</tbody>
</table>

In this regard, if we use water ($1000 \text{ kg/m}^3$) instead of mercury in a barometer, then the height of the water column must be $10.336\text{ m}$ i.e.

$$H(\text{water}) = \frac{P}{D_v g} = \frac{1.013 \times 10^5 \text{ Pa}}{1000 \text{ kg/m}^3 \times 9.8 \text{ kg/s}^2} = 10.33 \text{ m} \quad (3)$$

If the height of the water column is found to be more than $10.33 \text{ m}$, then it means the value of $g$ will be less than $9.8 \text{ m/s}^2$. Similarly, the inverse is also true. Thus sensitive experiments are required for precise conclusions.

Also for glycerine

$$H(\text{glycerine}) = \frac{P}{D_v g} = \frac{1.013 \times 10^5 \text{ Pa}}{1260 \text{ kg/m}^3 \times 9.8 \text{ kg/s}^2} = 8.202 \text{ m} \quad (4)$$

Like this, many other barometers are possible using different liquids, so for proper understanding the phenomena, there are many possibilities. Such experiments have to be conducted in tubes of different diameters including the capillary tube. Due to capillarity, the mercury is depressed and water rises in the capillary tube. Practically viscosity offers internal resistance/friction to movement of fluid. Consequently, the glycerine column must attain the desired height after a certain interval. Further, the angle of contact for glass and mercury is obtuse (does not wet the glass) and that of glass and water is acute (wets the glass). Apparently, this effect also may influence the height of the water column. The heights of liquid columns must be as above if eq. (1) is precisely obeyed for liquids other than mercury. If not, then $P$ will also depend upon other characteristics of fluids, then the method of measurement of pressure using a mercury column would be regarded as standard and mercury as the ideal liquid.
References

