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WILL RISING WATER DROPLETS CHANGE SCIENCE?

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ABSTRACT

The movement of liquid water droplets against the gravitational field has been shown. This was observed when projecting condensed steam droplets downwards. The observations show that the droplets decelerated and turned around at a point with their velocity becoming zero and begin moving upwards against the earth's gravitational attraction. Further to the above observation, condensed steam droplets kept in an inverted container were examined. Some of these droplets showed upward drift while others drifted downward. The higher density of water droplets relative to surrounding air doesn't satisfy the condition for the buoyancy to be responsible for the upward movement. The conditions required to create convection current were also not present at the region where droplets begin their upward movement. Therefore, no adequate explanation of this droplet movement against gravity can be given with conventional laws and hence a novel way of thinking is needed to explicate the behavior.

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Keywords: Gravity, density, buoyancy, convection, latent heat.

INTRODUCTION

Archimedes (287 BC – 212 BC) discovered a method of finding a forged gold crown. He discovered a technique in determining a property which is unique to each and every substance when he stepped into a bathtub and watched it overflow. He uncovered that the weight of the displaced fluid is equal to the apparent loss of weight of an object which is partially or totally immersed in the fluid. He realized that this unique property of a metal, density can be found from its weight and its weight loss in water. Subsequently the observation of Archimedes came to be established as the principle of Archimedes which is conveniently used in explaining some of the observations of nature. Although the concept of buoyancy originated with two different forms of matter (water and gold), it was then extended to any form of matter with different states of packing - tight or loose.

One of the most seen phenomena in nature is cloud formation. Condensation of water vapor in any air mass that becomes saturated above the Earth's surface creates clouds. Air containing water vapor is forced to rise because of the physical presence of elevated land or if sufficient surface heating occurs at the ground. The main constituents of atmospheric air; nitrogen (78%, molecular mass ~ 28.02amu), oxygen (21%, molecular mass ~ 32.00amu) and a trace of argon (0.93%, atomic mass ~ 39.94amu), which exists in mono atomic form and other gases such as carbon dioxide and water vapor. The average molecular mass of air is 28.97 g/mol. Assuming Avogadro's Law and the ideal gas law, water vapor and air will have a molar volume of 22.414 liter/mol at STP. A molar mass of air and water vapor occupy the same volume of 22.414 liters (http://www.tiptheplanet.com/wiki/Water, 2011). The molecular mass of water is 18.02 g/mol. The density (mass/volume) of water vapor is 0.804 g/liter, which is significantly less than that of dry air at 1.292 g/liter at STP. This means that at the same temperature, a column of dry air will be denser or heavier than a column of air containing any water vapor. Thus, any volume of moist air will rise/float if placed in a larger volume of dry air. This is the standard explanation of transport of water vapor leading to cloud formation. Hence, It appears that vertical drift generally observe in water vapor (due to surface heating) could be explained using Archimedes law of buoyancy.

Apart from the cloud formation there is one other interesting phenomena in nature called fog or mist which is mainly categorized by the number density and the size of the water droplets in air. If we can see more than 1 km through the cloud of water droplets, it is known as mist. If the visibility falls less than that, it is called fog. Mist and fog usually form on a calm night when the air is too cold to hold all its moisture. Volume mean diameter (VMD) of fog droplets are observed up to about 65μm (Kumar, 1973; Lenham and Clay, 1982) and in mist the VMD tends to be little higher than fog. In another word, mist is heavier and lies close to the ground. The separation

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among these droplets is relatively large compared to their size. The number density of these droplets is around 25 droplets per cm^3 (Kumar, 1973).

One curious observation is that these water droplets (fog or mist) float in an undisturbed atmosphere. This can be explained by the standard explanation of buoyancy because as stated above the density of water vapor is less than dry air. These droplets contain an enormous water quantity as single masses relative to the water vapor in the surrounding air. Each droplet is separated with a large distance relative to their size and no known forces exist among them other than the gravitational (Newton, 1687; Hawking and Israel, 1996; Flandern, 1996) and electromagnetic (Maxwell, 1865) forces which are experiences by all other objects in the universe.

One could ask a plausible question whether the concept of density could be correctly applied to the collection of widely separated water droplets where the inter-particle interactions are only of electromagnetic or gravitational nature. Hence, according to the traditional explanation we are considering the “dispersed water droplet state” as a bulk material or single object, such as a solid or a liquid when measuring the density. Therefore certain ambiguities arise when we apply Archimedean concept to this situation.

Figure 1 shows an example of water droplets, due to condensation of steam, coming out from a tube directed downward and changing direction and traveling upwards. The steam is in the gaseous phase which has been converted from its liquid form by acquiring Latent heat. According to the steam-tables the density of steam at 1 atm and 100 ^{0}C is 0.6 kg/liter. The picture (Fig. 1) shows the condensed-steam as a white cloud which indicates that the droplets/particles in the condensed-steam are large enough to reflect/scatter visible light. However, within the region where the condensed-steam is seen as a white mist, the particle dimension exceeds the order of the wavelength of the visual spectrum. Several studies (Fan *et al*., 2009; Tatsuno and Nagao, 2000; Cinar and Yilbas, 1998; Petr and Kolovratník, 2000) show that the size of these droplets/particles ranging up to several tens of microns, peaking around 0.1 – 0.5µm. Even a condensed-steam droplet (CSD) with 0.1µm diameter contains a rather large number of molecules making the CSD denser than its surrounding air. With this in mind how do water droplets in mist or fog float in air without falling down to the earth surface in the absence of air turbulent or convection currents? Also why do these water droplets in figure 1 with heavier density relative to the surrounding air go up? There are two possibilities. One is buoyancy (possibility 1) due to density of the displaced air volume by the CSD; this is similar to Archimedes’ explanation. The other possibility is that the resultant upward movement exerted by the rising hot air molecules (possibility 2) creating a convection current.

Fig. 1. Photograph of the path of condensed-steam or water droplets projecting downward direction. Photograph shows a stream droplets coming out from a tube downward direction and turning around and move upward. The droplets are visible as a white mist.

In this study, I examined the conditions required for possibilities 1 and 2 to drive water droplets in an upwards direction, which is against earth’s gravitational pull. For the 1st possibility the density of the CSD which is in liquid form has a higher density than that of surrounding hot air. The next question is that whether any temperature gradient is present which is required to create convection current that causes the rising of air molecules as seen in figure 1. For this I have shown that the condition required to create convection current is also not present at turning-around point (TAP). These 2 conditions were not met. This will lead to a clear doubt for the cause of the rise of CSD.

MATERIALS AND METHODS

Experimental

Ex.1

Steam produced by an electrically boiling water pot was sent in a downward direction through a tube as shown in figure 1. Rate of production of steam can be changed by the electric power supplied to the water pot and hence the velocity of the CSD coming out from the downward oriented tube. The temperature distribution and droplet movement of the emitting CSD were observed by imaging with Cryogenically cooled third generation forward looking infra red(FLIR)thermal camera 3-5µm and 7.5-13µm (Flir, model B-CAM) infrared (IR) wavelengths.

Ex. 2
Condensed-steam was over-filled in a vertical inverted container (bottom opened and top closed) as in figure 2. The temperature distribution, droplet size and their movement of the CSDs were measured as in Ex. 1. CSDs were illuminated by highly intense halogen light beam and a digital SLR camera was used to image droplet size at its optimum setting. A fine wire with a diameter 40µm was placed with condensed-steam in order to get approximate droplet size.

OBSERVATIONS

As seen in the figure 1, in Ex.1, downward projected CSDs come out from the tube and traveled some distance downward decelerating their speed and became zero at a point where the droplets turned around and started moving upwards. Temperature measured at the TAP by IR imaging is between 60^o-55^{o}C.

The upward movement of CSD is clearer in the Ex.2 due to slow movement of droplets at the bottom of the container. An interesting observation was that in Ex. 2, some of the CSDs drift upward from the edge of the container as shown in figure 2, while others drifted downward as leaving the container from the open bottom. Also there were some droplets which do not travel up or down bur rather just randomly float below the open bottom.

The observed water droplets in Ex.2 are also well recognized by the naked eye and movements are slow enough to be captured by a digital SLR (Fig. 3). The measured average diameter of water droplets is nearly 20µm, and the approximate separation among droplets were 0.32mm to several mm.

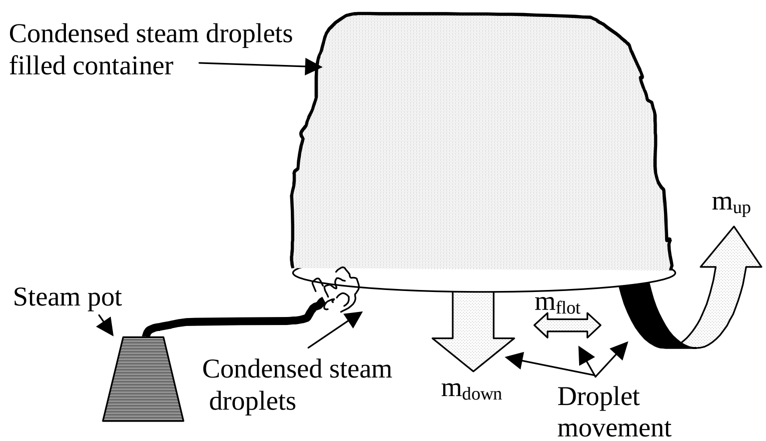


Fig. 2. Movement of the condensed-steam droplets in bottom opened container. Steam generated in a steam pot was fed into the container. The condensed-steam droplets inside the container made three kinds of movements, upward, downward and float at the same time. Infrared imaging clearly shows these three different droplet movements at the bottom of the container.

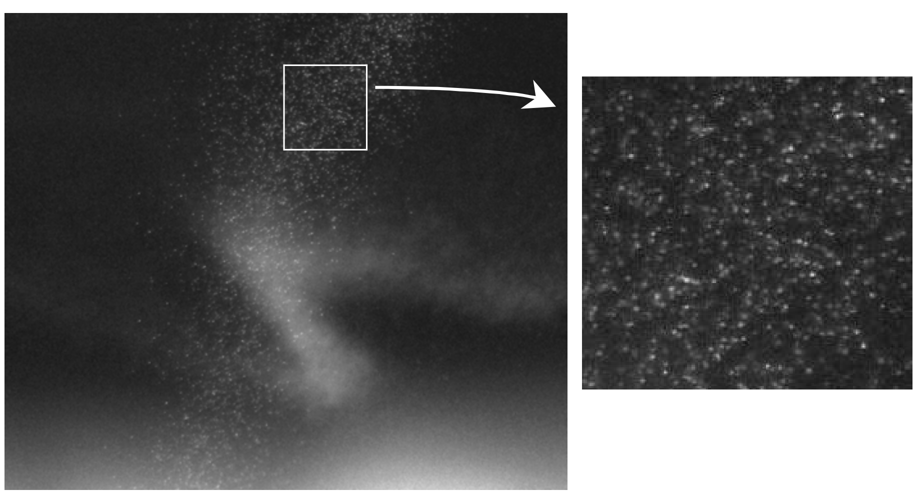


Fig. 3. Photograph of condensed-steam droplets. Water droplets are clearly seen. They are well apart and diameter is around 20µm and below.

DISCUSSION

Perfect gas law says that, density of dry air,

$$\rho_{dry} = \frac{p}{RT} \quad (1)$$

where p is the pressure in dry air, R is the specific gas constant and T is the absolute temperature. The density of air at STP is 1.264 Kg/m^3. CSD which are in the liquid phase at 90^{0}C has a density of ~ 965 kg/m^3 which is far greater than that of the density of air. The observation (Ex. 1) shows that almost all the visible water droplets emerging from the tube rise up. Hence Archimedes law of buoyancy is not a valid reason for the upward movement of the water droplet. So obviously the *possibility 1* itself is not the reason for the upward movement of CSDs.

According to the ideal gas law, the droplet will be uniformly bombarded by surrounding air molecules from all directions (Fig. 4 a). The total number of collisions, N_{coli} per unit time per unit area is given by

$$N_{coli} = \rho / 4\sqrt{8kT / \pi m_a} \quad (2)$$

where ρ is the particle density in unit volume, k is the Boltzmann constant, m_a is the mass of the air molecule. The velocity of the CSD coming down from the tube (Fig. 1) becomes zero at a certain depth and rises upwards. Figure 4(b) shows the forces acting on the droplet with mass m_s at the (TAP), assuming that the steam droplets have a spherical shape. F_b is the buoyancy force acting on steam droplet, F_l is the force exerted by rising air molecules (lift force). m_sg is the force due the gravitational field exerted by the earth. m_sg is approximately 825 times higher than F_b (when density of water @ 60^{o}C is 983kg/m^3. density of air @24^{o}C 1.19 kg/m^3). i.e. *Possibility 1* not met. Our next attempt is to check whether convection current exists in the turning around area and if so, is the magnitude strong enough to lift the droplet?

There is no primary thermal source below the TAP and only the radiation from the hot water droplet and water vapor emanating from the tube can cause temporary heating to activate convection. In other words, the temperatures measured at turn around point (t_{ta}) and just below (t_{jb}) should cause convection of surrounding air/vapor that leads to the upward lift of the CSD. Thermal image reveals that there is no significant increase

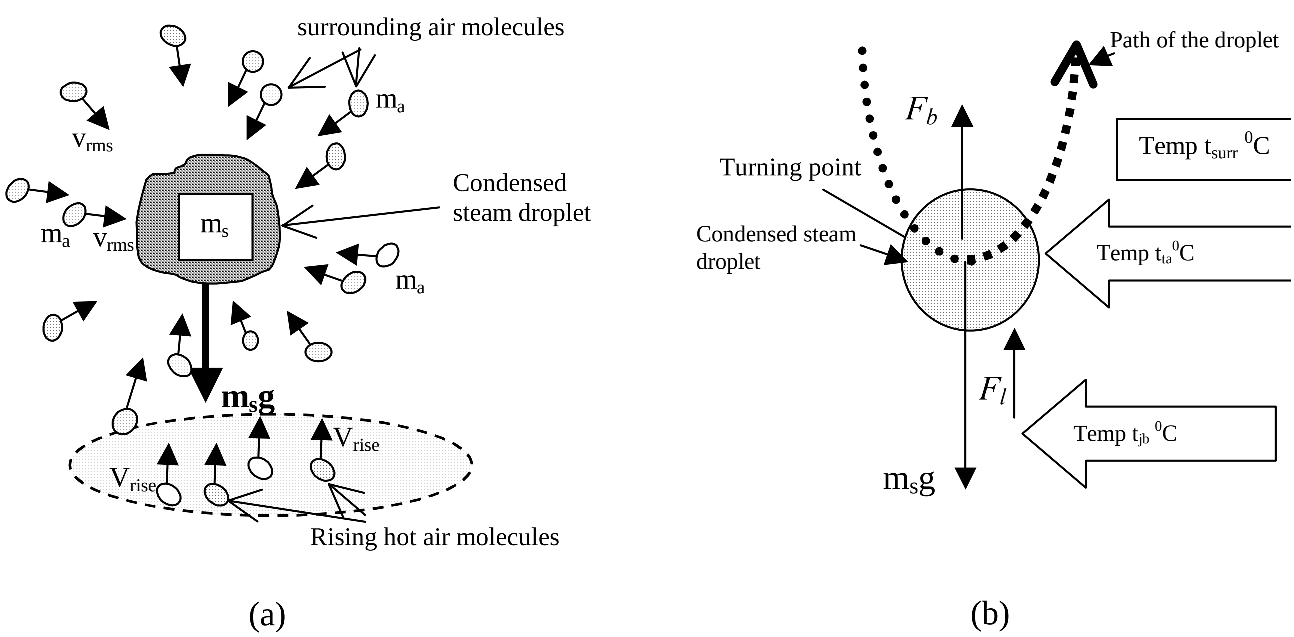


Fig. 4. Condensed-steam droplet in air. (a) CSD with mass m_s is subjected to the two kinds of influence by surrounding and rising air molecules. CSD is uniformly bombarded by surrounding air molecules from all directions while experiencing a force exerted by rising air. m_sg is the force exerted by the earth's gravitational field. (b) Figure shows the path and forces acting on the droplet at the turning-around point, assuming that the droplets have spherical shape. F_b is the buoyancy force acting on steam droplet, F_l is the force exerted by rising air. m_sg is the gravitational force and the temperature measured at turning-around point is 55^o – 60^{o}C. Below the TAP the temperature was approximately ~24^{0}C (RT).

in temperature measured below the turning point (Fig. 5) by the radiation of heated water droplets moving above. Instead a decreasing temperature gradient (Fig. 5c) is found. This does not support the upward movement of liquid or gas by the current knowledge of convection. Fig. 5a shows the thermal image of the TAP of CSD. The temperature intensities are converted in to a color gradient and presented in figure 5b for better visualization of the temperature distribution at the TAP. The lower part, from UV to XY shows (Fig. 5c) decreasing temperature from 60°C to 24°C (RT) which definitely inhibits any possible upward convection movement.

In Ex. 2, upward movement of CSD is prominent when the container is filled. With time, downward movement of CSDs arises. It is also observed that with time when downward movement of CSD is significant, there is also upward movement of CSDs present at the same time. See

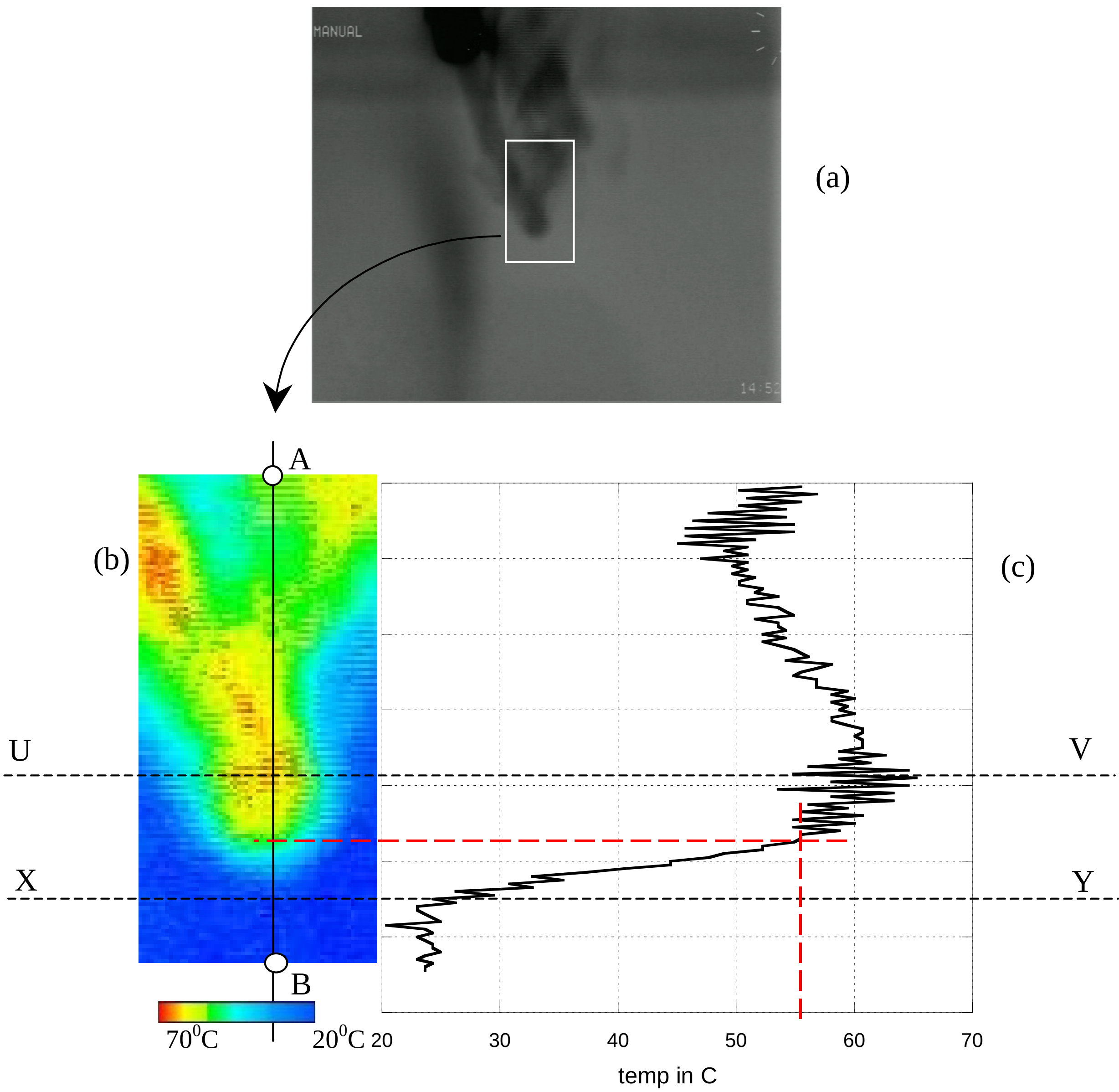


Fig. 5. Thermal image of TAP of the stream of CSD and the vertical temperature distribution of the middle of TAP area. (a) Thermal image of downward projected CSD taken from the Cryogenically cooled third generation forward looking infrared (FLIR)thermal camera (3-5µm). (b) Temperature distribution at the droplet turning around area. Color gradient is proportional to the temperature as shown in the plate below (c) Temperature distribution along the line AB in (b).

Fig. 6. In the meantime floating droplets around the mouth of the container were observed. The thermal images reveal that the temperature distribution in the bottom of the container lies between 50°-60°C. It is noted that the temperature at the lowermost point of the TAP is between 55-60°C in Ex. 1.

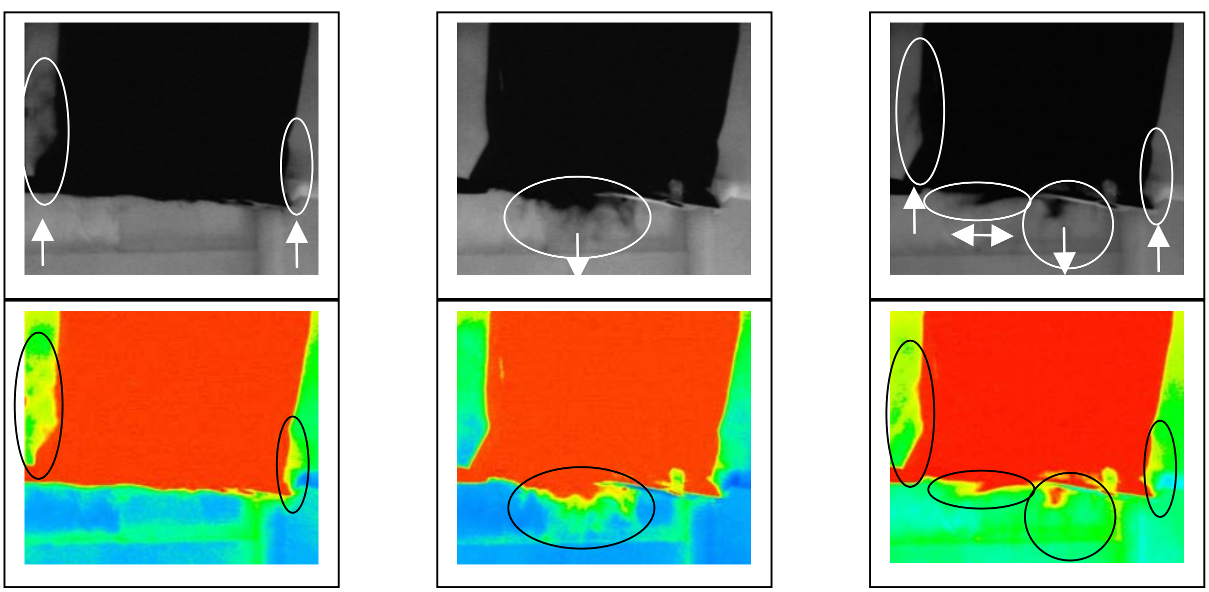
The forces acting on the water droplet at the TAP where its velocity become zero in a undisturbed surrounding can be written as

$$F_u = F_b + F_l \geq F_d = m_s g \tag{3}$$

where F_u is the total upward force, F_d is the total downward force, m_s is the mass of the condensed-steam droplet and g is the gravitational acceleration. It is shown that the ratio of densities of water to air at TAP in Ex.1 is approximately 825. i.e. $m_s g$ is approximately 825 times higher than F_b. However, there is no apparent rise of temperature (hence, the convection current) just below the turning point of condensed-steam droplets. In the absence of the known forces, that cause the rising of CSD, arises possibility of whether there is unknown force acting on the droplet.

Downward heat evaporated iodine in a vacuum chamber has also shown similar upward movement against the direction of gravitational attraction (Piyadasa, 2011) in the absence of buoyancy and convection lift. In that experiment, it is observed that iodine was in independent/isolated cluster state (liquid and/or gaseous state) with a certain amount of latent heat. A similar situation is seen with the condensed-steam droplets which contains molecular cluster (as droplet) with certain amount of latent energy (as hidden internal energy). Within the temperature range of 50° – 60°C at mouth of inverted container in Ex.2, some upward and some downward moving CSDs having diameter under 20μm were observed. Above approximately 55°C at TAP almost all the droplets moved upward as in Ex. 1. As seen in figure 6 droplet may experience net upward force F_u and net downward force F_d depending on its temperature and its weight. With the increase of time, CSD cools by radiation and also increased by weight by condensation of surrounding water vapor.

To the present knowledge, the upward force F_u is only due to buoyancy and lift caused by the convection of surrounding air. Both these mechanisms do not explain the situation where upward movement of CSD as shown elsewhere Piyadasa (2011). Downward force F_d is due to the weight of the droplet and could be due to increase of condensation with time and thereby increase of the weight of the droplets. Simultaneously radiation/convection loss of heat reduces its internal energy which is mainly stored as latent heat. In all three experiments, evaporated Iodine and condensed steam droplets, the common feature was the latent heat. Therefore a plausible explanation could lie in the temperature differences of the CSDs.



(a) (b) (c)

Fig. 6. Thermal images of condensed-steam filled vertically inverted container. Upper - B/W. and Lower - Color gradient is proportional to the temperature as shown in the plate in Fig. 5 (a) water droplets move upwards (b) water droplets move downwards (c) some of the water droplets move upwards while others move downward. Some droplets randomly float below the open bottom of the inverted container.

CONCLUSIONS

Now that the buoyancy force and convection force are untenable due to the density and temperature profile in the media respectively, thus we have to speculate the driving force behind the upward movement of condensed-steam droplets against gravity in the atmosphere. It seems that the latent heat/internal energy of the CSD may be related to the upward force. With buoyancy and convection ruled out as the cause of the upward mobility in the particles observed, strongly suggests an unknown force, it could be Antigravity: perhaps, an avenue for further research.

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