IV. Memoir on tubes rendered harmonious by hydrogen gas. Read before the Society of Physics and Natural History of Geneva

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Consequently, by suppressing from the colours of hard porcelain the carmine of gold, which is not indispensably necessary, we shall have a series of colours which do not change, and which will be absolutely similar to those presented to the Institute in the year 6.

IV. *Memoir on Tubes rendered harmonious by Hydrogen Gas. Read before the Society of Physics and Natural History of Geneva, by G. DELARIVE, Ex-President of the Royal Society of Edinburgh, and Member of the Medical Colleges of London and Geneva*.*

IN a former sitting, our learned colleague professor Pictet communicated to the society a series of recherches on tubes rendered harmonious by means of hydrogen gas, and explained the different musical phenomena to which these tubes give birth. He pointed out the influence of the length of the tube; of its breadth, and of the place where the gas is burnt; and explained the nature of the sounds produced. In regard to the cause of the sound, he offered only conjectures: as his labour was not directed to that object, it is under this point of view that I have resumed it.

Professor Brugnatelli, in my opinion, is the first person who published the experiment; which I shall endeavour to explain. It had been invented by a German: I shall here give a view of the principal circumstances attending it.

If a current of inflamed hydrogen gas be introduced into a tube the substance of which is elastic and sonorous, such as glass, metal, dry wood, &c., this tube, after the interval of some seconds, will emit a harmonic sound: if it be open at both extremities, the sound will be strong and full. The experiment may, however, succeed with a tube closed hermetically at one end, provided its diameter be so large as to admit of a circulation of the atmospheric air in sufficient quantity to maintain the combustion of the gas. The conditions essentially necessary for this purpose are: 1st, That the substance of the tube be elastic, proper for producing an echo; that is to say, for reflecting the undulations which proceed from the sonorous point: a tube of paper or pasteboard will emit no sound. 2d, The flame must be produced by a current of hydrogen gas. An inflamed jet of the vapour of spirit of wine or ether, a lighted taper, &c. are incapable of making the tube emit any sound.

* From the *Journal de Physique*, Fructidor, an. 10.

Let us now examine what takes place in this experiment. There must be a certain point, which may be called the *sonorous point*; it is at this point that the vibrations which communicate to the air an undulatory motion are produced. This point is the place of combustion; for by changing the position of that place the sounds may be varied, as M. Piçet proved by a series of experiments. This gentleman observed also in that point, by means of the smoke with which he filled the tube, a continual succession of vibrations. These vibrations give birth to undulations, which are propagated with a known and determined velocity, and, striking the sides of the tube, are reflected with the same velocity as that with which they reached them. When the distance of the sides of the tube is such that the reflections backwards and forwards are isochronous with the vibrations natural to the sonorous cause, the sound increases in intensity, and becomes musically appreciable. It appears also that the reflected undulations re-act on the primitive vibrations produced in the place of combustion, and render them harmonically regular with them; for a certain space of time is almost always necessary before the instrument has acquired a regular and full sound: the tone of the tube will be higher or lower according to the greater or less number of undulations which take place in a given time.

There is another essential fact to be observed in the experiment which we here examine: the temperature of the column of air is not the same throughout its whole length. At the sonorous point, that is to say, the place of combustion, the temperature is exceedingly high; it is such, that the extremity of the aperture of the glass through which the hydrogen gas issues is constantly in a state of incandescence: if an inflamed jet of the vapour of spirit of wine or ether be substituted for a current of hydrogen gas, the heat is visibly weaker. According to some experiments it appears probable also that the temperature of the chamber where the experiment is made, and the purity of the air in the chamber, may have some influence on the result.

The object of my researches was to discover the cause of these phænomena, and how, and by what means, these sonorous vibrations are produced. During the combustion of hydrogen gas, it is well known that there is a production of water, and this water appears under the form of vapours. The place of the combustion being at a high temperature, these vapours must acquire a large volume; but, coming immediately into contact with air less heated, their volume must be rapidly diminished. A vacuum therefore must be formed,

into which the air rushes to be repelled by the new vapours, that contract in their turn. Is it from this alternate motion, produced by the great expansion and subsequent contraction of the vapours, that the sonorous vibrations result * ?

Such were the conjectures which might be formed on the probable cause of this phenomenon, when I accidentally met with a fact which appeared to me to give them some weight.

I had a thermometer tube about a line in diameter, at the extremity of which a small bulb was blown. In this bulb was a drop of water, which I wished to expel : for this purpose I exposed the bulb several times to the flame of a spirit-of-wine lamp. I was agreeably surprised to hear the tube emit a harmonious sound.

To repeat this experiment with success, the tube employed must be from 1 to 2 or 3 lines in diameter : its length may be about from 3 to 4 or 5 inches : it must have blown at one of its extremities a bulb the diameter of which is about triple that of the tube. It is not necessary that it should be regular. It even appears that, if it were a little flatted, the sound emitted would be higher. Into this bulb introduce a little quantity of water or mercury, and then expose it to a strong heat : that of a common spirit-of-wine lamp will, in general, be sufficient ; but the flame must be large and strong when the operation is performed with a large tube. After the bulb has been exposed for some moments to the heat, it will emit a sound. Tubes of a large diameter produce a sound lower

* It appears to me probable that the sound produced by the air which rushes into the vacuum is more intense than that which results from an expansive force. The dreadful noise occasioned by the detonation of bubbles of hydrogen gas and oxygen is well known, and yet the lightest objects which surround the vessel are not even agitated by it ; whence we may conclude that this phenomenon is produced by the sudden vacuum resulting from the destruction of the gas. The detonation of an inflammable gas pistol is much stronger than that of the air-gun, though the effect is less considerable ; probably because in the pistol a vacuum succeeds the first expansive force. Every body is acquainted with that children's plaything called the humming top. It consists of a hollow sphere with an aperture at the circumference, which being made to turn rapidly on its axis produces a very strong humming noise. What is the cause of this noise ? The same, in my opinion, as that above mentioned : the centrifugal force expels the air from the sphere through its aperture ; a kind of vacuum is formed in it, the exterior air continually tends to enter it, and is immediately repelled, and hence a series of sonorous oscillations. — The AUTHOR.

The effect here spoken of seems rather to arise from the velocity with which the edge or lip of the orifice meets the air ; for the same sound may be produced by directing a stream of air against the lip when the top is stationary. — EDIT.

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than others. The size of the bulb appears to me also to contribute towards the same effect. The sound will be permanent for some moments; it will then gradually decrease, and at length will entirely cease. By suffering the apparatus to cool, and taking care to make the liquid condensed along the sides of the tube to descend into the bulb, the experiment may be repeated as often as may be thought proper.

Such is the experiment by means of which, in my opinion, the phenomenon of the harmonious tubes may be explained in a satisfactory manner. Let us now examine what takes place in tubes with a bulb, and what are the essential conditions necessary to make them emit a sound, and let us endeavour to discover the cause of this sound. We shall then compare them with the tubes employed with hydrogen gas, and shall examine in what these two instruments resemble each other in the effects they produce, the differences they exhibit under the same relations, and the causes of these differences.

The essential conditions necessary to make tubes with a bulb resound are: 1st, That the vessel has a bulb: I was never able to excite sonorous vibrations in a tube simply closed at one of its extremities. 2d, This bulb must contain an evaporable liquid: water succeeds very well; but it is attended with the disadvantage of forming in the tube, when it passes from the state of vapour to the liquid state, a small drop which often obstructs it entirely, and, sometimes, falling on the heated part of the glass, occasions a rupture. Mercury is not attended with the same defect: I was never able to produce sounds with ether, spirit of wine, or concentrated sulphuric acid. The quantity of liquid contained in the bulb is not a matter of indifference; it must be as small as possible: if there be too much, the tube becomes filled with vapours, which completely expel the air from it, and, heating it every where in an uniform manner, it no longer emits any sound. The third essential condition is the application of a strong heat to the bulb while the rest of the tube remains cold; for, if there be not a very striking difference of temperature between the bulb and the tube, there will be no sonorous effect. In the last place, the presence of atmospheric air is indispensably necessary: if it be entirely expelled, no effect can be produced. In all the periods of the experiment it will be found that the vapour fills only a certain portion of the instrument, and that it always contains air. I made several trials to determine exactly the space occupied by the vapour at the moment when the sound is heard; and I have found that, in small tubes at least, this space is somewhat less than

than the volume of the bulb. To determine it, I shut with my finger the orifice of the tube: at the moment when it began to sound, I immersed the orifice in mercury, removed my finger, and left the apparatus to cool. The vapour became condensed; and I could judge, by the quantity of mercury which the pressure of the atmospheric air made to ascend in the tube, the space which the vapour had occupied.

Such are the four conditions essentially necessary for obtaining sounds: a bulb at the extremity of the tube; the presence of a very small quantity of water or mercury in the bulb; the application of a strong heat to the bulb while the rest of the tube remains cold; and, in the last place, the simultaneous presence in the apparatus of vapour and atmospheric air. It is not necessary to add, that the orifice of the tube must always be open. Let us now examine what may be the cause of the sound. I wished first to ascertain whether any chemical decomposition of the liquid employed took place. For this purpose I took a tube of such a length that the liquid might be entirely condensed in it. I weighed it carefully before I made the experiment: I then made it emit sounds, and found, after producing this effect several times, that its weight had neither increased nor decreased; whence I concluded that caloric produces no chemical effect on the liquid, and that the latter merely undergoes successive evaporation and condensation. Is it to this evaporation, then, of the liquid, and its condensation, that the sounds ought to be ascribed? At first I believed that this question might be answered in the affirmative; but the following considerations made me change my opinion: I first observed that there might be a successive evaporation and condensation, without the tube emitting any sound, on applying to the bulb a sufficient heat, but less intense than that necessary for making the tube sound. Secondly, in making the experiment with a drop of water, I constantly found that the moment when the apparatus began to enter into action was that when the whole of the water was evaporated, and, consequently, when the heat acted on the vapour: if a single atom of liquid remained in the bulb, the tube was mute. From this fact I conclude that the sound is produced by the action of the caloric on the vapour, and the reaction of the latter on the atmospheric air. The following is the manner in which I conceive that this phenomenon takes place: The vapour contained in the bulb receives, by an addition of caloric conveyed to it from every part in a large quantity, an increase of volume and of elasticity; it proceeds with force from the bulb to the tube, and expels the air contained in it; but this air and the sides
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of the tube take from it, at the moment of contact, a portion of the caloric, its volume decreases, at the same instant a vacuum takes place, and the air resumes its primitive space. A new addition of caloric restores to the vapour its whole elasticity, a part of which it soon loses in the same manner. This is a consequence of the oscillations of that nature which give to the air an undulatory movement. The undulations reflected by the sides of the tube become sonorous and appreciable when they are isochronous with the oscillations produced by the cause I have indicated. From some tubes it is impossible to produce any sound: in these I am of opinion that the reflected undulations cannot harmonize with the primitive oscillations, and that the one destroy the other. In tubes with bulbs, the sound, after a certain time, becomes weaker, and at length ceases. This may be explained by the propagation of heat along the sides. When the bulb is very warm, and the tube cold, the vapour which rises from the bulb suddenly loses a part of its volume, and the oscillations thus produced are strong and frequent; but when the tube has acquired a certain degree of heat, the vapour gradually decreases in volume by passing from a very hot temperature into a place less warm indeed, but which, however, has a sufficient degree of heat to make the oscillations, which become weaker and fainter, to cease at length entirely. That such is the cause of the cessation of the sound may be proved by applying a strong heat to the part of the tube already heated, maintaining at the same time the same degree of heat under the bulb: by these means the limits of the temperatures are again very abrupt, and the sound will be reproduced in its full force. It may be readily conceived that the substance of the tube must be some matter a non-conductor of heat: glass, therefore, is preferable.

Let us now compare the apparatus of a tube having a bulb with those tubes in which hydrogen gas is employed. In the latter we have every thing necessary for the production of sound, a vapour very hot, and consequently highly elastic; for, as already observed, the place of the combustion is at so high a temperature that the beak of the glass is constantly red. This hot and elastic vapour, at the moment of its production, is in contact with the cold air, which enters the tube at the bottom and issues at the top; its volume must then decrease a moment after it has touched that cold air: new hot vapours succeed the former, and contract in their turn. This alternate expansion and contraction gives birth to the undulatory movement of the air, and sonorous undulations.

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We have already seen that an inflamed jet of spirit of wine or of ether cannot make the tube found. This is a new proof of what I have advanced, that to produce found there must be a great difference between the temperature of the vapour and that of the surrounding air. In this case there is a successive formation and condensation of vapour, for the water streams along the sides of the tube; but the place of combustion has a much inferior degree of heat to what it has when hydrogen gas is burnt, and consequently the vapour produced has less heat as well as less elasticity. This case is analogous to that already mentioned, when we said that a successive evaporation and condensation of the liquid might be produced in a tube having a bulb, without any sonorous effects, by exposing the bulb to a certain degree of heat, but less intense than that necessary for making the tube emit a found. We should not be surprised if less heat were produced by the combustion of spirit of wine, or ether, than by that of hydrogen gas, when it is considered that in the latter case all the caloric contained in this gas, and in the oxygen of the atmospheric air consumed, becomes sensible heat, and unites itself entirely with the vapour produced. On the other hand, in the combustion of an inflammable substance, such as spirit of wine, we have only the caloric of the oxygen consumed, rendered sensible, and which is in a great measure absorbed by the formation of carbonic acid gas, so that it is only the excess which joins the vapour. It is therefore not astonishing that we have not heat sufficient to give to this vapour all the elasticity necessary for the production of found: the presence of the carbonic acid gas resulting from the combustion may also be an obstacle to the sonorous vibrations.

In tubes employed with hydrogen gas, the found is much stronger than in those having bulbs: besides, in the former it is permanent, in the latter it continues only a few moments. The reason of this is as follows: In the apparatus with hydrogen gas the tube is open at both extremities, consequently there is formed a current of fresh air, which enters at the bottom and issues at the top; this current of air sweeping along with the hot and elastic vapours receives their impulse, and, by taking from them a portion of caloric, diminishes their volume: we find here, therefore, the most essential condition for the production of an intense and permanent found, viz. a great difference between the temperature of the air and that of the vapour; and this difference always remains the same by the continual renovation of the air; but this does not take place in tubes with bulbs, and therefore the found they emit is weaker and of shorter duration.

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From this principle, that the great difference between the temperature of the vapour and air is necessary for the production of sound, it may be easily conceived that every thing which tends to augment the heat of the current of air, and to diminish that produced by the combustion of the gas, will tend also to weaken or even to annihilate the sound of the tube: but these two circumstances are united in a warm chamber filled with people: the current of air, instead of being cool, is hot, and the quantity of oxygen being there less, the heat produced will be of less strength. It needs therefore excite no astonishment, that in such chambers the experiment does not always succeed.

Brugnatelli produced sounds in tubes merely by the combustion of phosphorus. Some philosophers, conceiving that the sonorous effects were owing in a peculiar manner to the hydrogen gas, have been induced to infer the presence of that substance in phosphorus. From what has been said, is it not more simple to explain this phenomenon by the production of the phosphorous acid under the form of vapours, which receive a great degree of elasticity from the caloric disengaged during the combustion, and the volume of which is soon diminished by the contact of the cold air? We find there the alternate expansion and contraction necessary for communicating to the air the undulatory motion proper for producing sounds.

Such are the few observations I have had an opportunity of making on harmonious tubes; I hope they will prove in some measure interesting to those particularly engaged with this branch of philosophy, and that they will contribute towards making them pay attention to this curious fact hitherto neglected.

V. *On Painting.* By Mr. E. DAYES, *Painter.*

ESSAY V.

On Invention.

Then, bold Invention, all thy powers diffuse,
Of all thy sisters thou the noblest muse;
Thee ev'ry art, thee ev'ry grace inspires,
Thee PIERCE fills with all his brightest fires.

MASON'S FRESNOY.

WE should never forget that the value of every art arises from the degree of mental capacity requisite to its production, and the degree of instruction or pleasure resulting therefrom.
Hence