XIV. *Electrical Experiments made in order to aſcertain the non-conducting Power of a perfect Vacuum*, &c. *By Mr.* William Morgan; *communicated by the Rev.* Richard Price, *LL.D. F.R.S.*

Read February 24, 1785.

THE non-conducting power of a perfect vacuum is a fact in electricity which has been much controverted among philoſophers. The experiments made by Mr. WALSH, F.R.S. in the double barometer tube clearly demonſtrated the impermeability of the electric *light* through a vacuum; nor was it, I think, precipitate to conclude from them the impermeability of the electric *fluid* itſelf. But this concluſion has not been univerſally admitted, and the following experiments were made with the view of determining its truth or fallacy. When I firſt attended to the ſubject, I was not aware that any other attempts had been made beſides thoſe of Mr. WALSH; and though I have ſince found myſelf to have been in part anticipated in one of my experiments, it may not perhaps be improper to give ſome account of them, not only as they are an additional teſtimony in ſupport of this fact, but as they led to the obſervation of ſome phænomena which appear to be new and intereſting.

A mercurial gage B (ſee tab. IX. fig. 1.) about 15 inches long, carefully and accurately boiled till every particle of air was expelled from the inſide, was coated with tin-foil five inches down from its ſealed end (A), and being inverted into mercury

mercury through a perforation (D) in the braſs cap (E) which covered the mouth of the ciſtern (H), the whole was cemented together, and the air was exhauſted from the inſide of the ciſtern through a valve (C) in the braſs cap (E) juſt mentioned, which producing a perfect vacuum in the gage (B) afforded an inſtrument peculiarly well adapted for experiments of this kind. Things being thus adjuſted (a ſmall wire (F) having been previouſly fixed on the inſide of the ciſtern to form a communication between the braſs cap (E) and the mercury (G) into which the gage was inverted) the coated end (A) was applied to the conductor of an electrical machine, and notwithſtanding every effort, neither the ſmalleſt ray of light, nor the ſlighteſt charge, could ever be procured in this exhauſted gage. I need not obſerve, that if the vacuum on its inſide had been a conductor of electricity, the latter at leaſt muſt have taken place, for it is well known (and I have myſelf often made the experiment) that if a glaſs tube be exhauſted by an air-pump, and coated on the outſide, both light and a charge may very readily be procured. If the mercury in the gage be imperfectly boiled, the experiment will not ſucceed; but the colour of the electric light, which, in air rarefied by an exhauſter, is always violet or purple, appears in this caſe of a beautiful green, and, what is very curious, the degree of the air's rarefaction may be nearly determined by this means; for I have known inſtances, during the courſe of theſe experiments, where a ſmall particle of air having found its way into the tube (B), the electric light became viſible, and as uſual of a green colour; but the charge being often repeated, the gage has at length cracked at its ſealed end, and in conſequence the external air, by being admitted into the inſide, has gradually produced a change in the electric light from green to blue, from blue to indigo, and

ſo on to violet and purple, till the medium has at laſt become ſo denſe as no longer to be a conductor of electricity. I think there can be little doubt from the above experiments of the non-conducting power of a perfect vacuum; and this fact is ſtill more ſtrongly confirmed by the phænomena which appear upon the admiſſion of a very minute particle of air into the inſide of the gage. In this caſe the whole becomes immediately luminous upon the ſlighteſt application of electricity, and a charge takes place, which continues to grow more and more powerful in proportion as freſh air is admitted, till the denſity of the conducting medium arrives at its maximum, which it always does when the colour of the electric light is indigo or violet. Under theſe circumſtances the charge may be ſo far increaſed as frequently to break the glaſs. In ſome tubes, which have not been completely boiled, I have obſerved, that they will not conduct the electric fluid when the mercury is fallen very low in them, yet upon letting in air into the ciſtern (H), ſo that the mercury ſhall riſe in the gage (B), the electric fluid, which was before latent in the inſide, ſhall now become viſible, and as the mercury continues to riſe, and of conſequence the medium is rendered leſs rare, the light ſhall grow more and more viſible, and the gage ſhall at laſt be charged, notwithſtanding it has not been near an electrical machine for two or three days. This ſeems to prove, that there is a limit even in the rarefaction of air, which ſets bounds to its conducting power; or, in other words, that the particles of air may be ſo far ſeparated from each other as no longer to be able to tranſmit the electric fluid; that if they are brought within a certain diſtance of each other, their conducting power begins, and continually increaſes till their approach alſo arrives at its limit, when the particles again become ſo near as to reſiſt the paſſage

of the fluid entirely, without employing violence, which is the caſe in common and condenſed air, but more particularly in the latter. Theſe experiments, however, belong to another ſubject, and may poſſibly be communicated at ſome future time.

It is ſurpriſing to obſerve, how readily an exhauſted tube is charged with electricity. By placing it at ten or twelve inches from the conductor the light may be ſeen pervading its inſide, and as ſtrong a charge may ſometimes be procured as if it were in contact with the conductor: nor does it ſignify how narrow the bore of the glaſs may be; for even a thermometer tube, having the minuteſt perforation poſſible, will charge with the utmoſt facility; and in this experiment the phænomena are peculiarly beautiful.

Let one end of a thermometer tube be ſealed hermetically. Let the other end be cemented into a braſs cap with a valve, or into a braſs cock, ſo that it may be fitted to the plate of an air-pump. When it is exhauſted, let the ſealed end be applied to the conductor of an electrical machine, while the other end is either held in the hand or connected to the floor. Upon the ſlighteſt excitation the electric fluid will accumulate at the ſealed end, and be diſcharged through the inſide in the form of a ſpark, and this accumulation and diſcharge may be inceſſantly repeated till the tube is broken. By this means I have had a ſpark 42 inches long, and, had I been provided with a proper tube, I do not doubt but that I might have had a ſpark of four times that length. If, inſtead of the ſealed end, a bulb be blown at that extremity of the tube, the electric light will fill the whole of that bulb, and then paſs through the tube in the form of a brilliant ſpark, as in the foregoing experiment; but in this caſe I have ſeldom been able to repeat the trials above three or four

times before the charge has made a ſmall perforation in the bulb. *If again a thermometer filled with mercury be inverted into a ciſtern*, and the air exhauſted in the manner I have deſcribed for making the experiment with the gage, a Torricellian vacuum will be produced; and now the electric light in the bulb, as well as the ſpark in the tube, will be of a vivid green; but the bulb will not bear a frequent repetition of charges before it is perforated in like manner as when it has been exhauſted by an air-pump. It can hardly be neceſſary to obſerve, that in theſe caſes the electric fluid aſſumes the appearance of a ſpark *, from the narrowneſs of the paſſage through which it forces its way. If a tube, 40 inches long, be fixed into a globe 8 or 9 inches in diameter, and the whole be exhauſted, the electric fluid, after paſſing in the form of a brilliant ſpark throughout the length of the tube, will, when it gets into the inſide of the globe, expand itſelf in all directions, entirely filling it with a violet and purple light, and exhibiting a ſtriking inſtance of the vaſt elaſticity of the electric fluid.

I cannot conclude this paper without acknowledging my obligations to the ingenious Mr. BROOK, of Norwich, who, by communicating to me his method of boiling mercury, has been the chief cauſe of my ſucceſs in theſe experiments †. I have lately learned

* By cementing the ſtring of a guittar into one end of a thermometer tube, a ſpark may be obtained as well as if the tube had been ſealed hermetically.

† Mr. BROOK's method of making mercurial gages is nearly as follows. Let a glaſs tube L (ſee fig. 2.), ſealed hermetically at one end, be bent into a right-angle within two or three inches of the other end. At the diſtance of about an inch or leſs from the angle let a bulb (K), of about $\frac{3}{4}$ of an inch in diameter, be blown in the curved end, and let the remainder of this part of the tube be drawn out (I) ſo

learned from him, that he has alſo aſcertained the non-conducting power of a perfect vacuum; but what ſteps he took for that purpoſe I know not. Of his accuracy, however, I am ſo well convinced, that had I never made an experiment myſelf, I ſhould, upon his teſtimony alone, have been equally aſſured of the fact. To moſt of the preceding experiments Dr. PRICE, Mr. LANE, and ſome others of my friends, have been eye-witneſſes, and I believe that they were as thoroughly ſatisfied as myſelf with the reſults of them. I muſt beg leave to obſerve to thoſe who wiſh to repeat them, that the firſt experiment requires ſome nicety, and no inconſiderable degree of labour and patience. I have boiled many gages for ſeveral hours together without ſucceſs, ſo as to be ſufficiently long to take hold of, when the mercury is boiling. The bulb (K) is deſigned as a receptacle for the mercury, to prevent its boiling over, and the bent figure of the tube is adapted for its inverſion into the ciſtern; for by breaking off the tube at (M) within $\frac{1}{8}$ or $\frac{1}{4}$ of an inch of the angle, the open end of the gage may be held perpendicular to the horizon when it is dipped into the mercury in the ciſtern, without obliging us to bring our finger, or any other ſubſtance, into contact with the mercury in the gage, which never fails to render the inſtrument imperfect. It is neceſſary to obſerve, that if the tube be fourteen or fifteen inches long, I have never been able to boil it effectually for the experiments mentioned in this paper in leſs than three or four hours, although Mr. BROOK ſeems to preſcribe a much ſhorter time for the purpoſe; nor will it even then ſucceed, unleſs the greateſt attention be paid that no bubbles of air lurk behind, which to my own mortification I have frequently found to have been the caſe; but experience has at length taught me to guard pretty well againſt this diſappointment, particularly by taking care that the tube be completely dry before the mercury is put into it; for if this caution be not obſerved, the inſtrument can never be made perfect. There is, however, one evil which I have not yet been able to remedy; and that is, the introduction of air into the gage, owing to the unboiled mercury in the ciſtern; for when the gage has been a few times exhauſted, the mercury which originally filled it becomes mixed with that into which it is inverted, and in conſequence the vacuum is rendered leſs and leſs perfect, till at laſt the inſtrument is entirely ſpoiled. I have juſt conſtructed a gage ſo as to be able to boil the mercury in the ciſtern, but have not yet aſcertained its ſucceſs.

and

and was for ſome time diſpoſed to believe the contrary of what I am now convinced to be the truth. Indeed, if we reaſon *a priori*, I think we cannot ſuppoſe a perfect vacuum to be a perfect conductor without ſuppoſing an abſurdity: for if this were the caſe, either our atmoſphere muſt have long ago been deprived of all its electric fluid by being every where ſurrounded by a boundleſs conductor, or this fluid muſt pervade every part of infinite ſpace, and conſequently there can be no ſuch thing as a perfect vacuum in the univerſe. If, on the contrary, the truth of the preceding experiments be admitted, it will follow, that the conducting power of our atmoſphere increaſes only to a certain height, beyond which this power begins to diminiſh, till at laſt it entirely vaniſhes; but in what part of the upper regions of the air theſe limits are placed, I will not preſume to determine. It would not, perhaps, have been difficult to have applied the reſults of ſome of theſe experiments to the explanation of meteors, which are probably owing to an accumulation of electricity. It is not, however, my preſent deſign to give looſe to my imagination. I am ſenſible, that by indulging it too freely, much harm is done to real knowledge; and therefore, that one fact in philoſophy well aſcertained is more to be valued than whole volumes of ſpeculative hypotheſes.

Chatham-Place, Feb. 12, 1785.

Fig. 1.

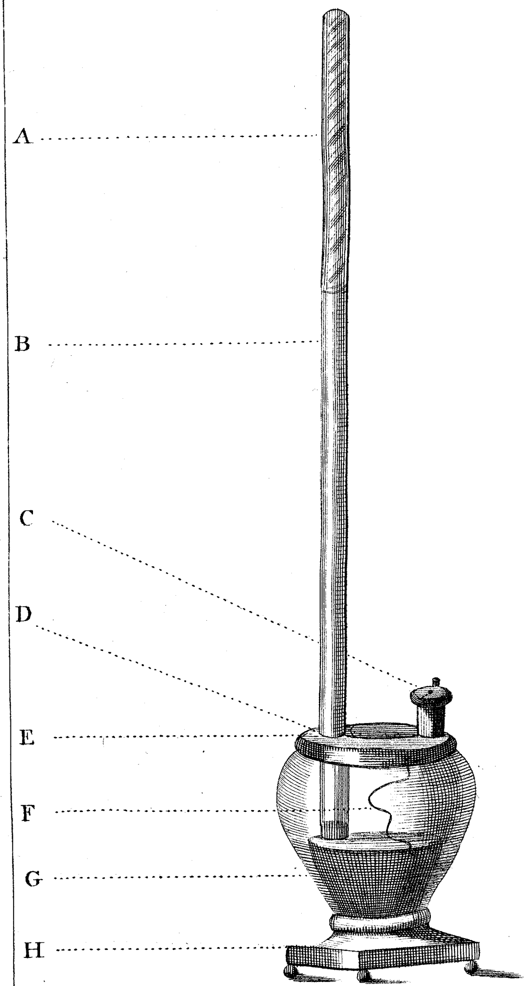
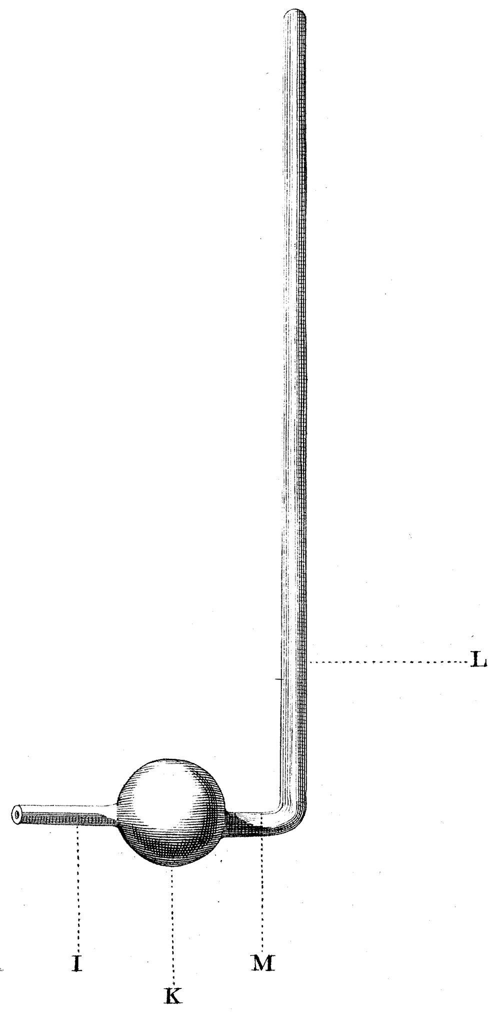


Fig. 2.



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