APPENDIX A

A TRANSLATION OF LICHTENBERGS PAPER OF 1777 FROM LATIN TO ENGLISH

The following paper is included in this thesis due to its historic interest. An extensive international library search failed to find an English translation of this paper. The original Latin version was obtained from the University of Goettingen, Germany and has been translated into English by Mr. Joseph Blain, Classics Department, McGill University with technical assistance by the author of this thesis. A French text written by Lichtenberg in 1780 was also consulted.

In this translation references are given by letters and numbers in curved brackets, eg. (a), (1). The letters signify the author's original references while the numbers refer to translator's notes. Both author's references and translator's notes are contained at the end of the paper.

In translating this paper Mr. Blain has adopted a literal translation approach and therefore the English may at times appear strained. This approach was used so that the expert reader could better interpret the meaning of this scientific work.

GEO. CHRIST. LICHTENBERGII

DE

NOVA METHODO NATVRAM AC MOTVM FLVIDI ELECTRICI INVESTIGANDI

COMMENTATIO PRIOR,

EXPERIMENTA GENERALIORA CONTINENS.

LECTA

IN CONSESSV PVBLICO SOCIETATIS REGIAE SCIENTIARVM.

D. XXI. FEBR. MDCCLXXVIII.

Inter notabiliora, quibus recens ditata eſt doctrina de Electricitate, inventa, haud immerito cenſendus eſt Electrophorus, cujus inventorem Cel. Wilckium Vismarienſem, Phyſices nunc Holmiae Profeſſorem, concivem olim noſtrum, appellare non dubito *a*). Cel. Volta enim, hanc machinam non tam invenit, quam adparatum inſtrumentorum, quem, ad demonſtranda quaedam circa experimenta Lugdunenſia phaenomena, ex vitro jam Ao. 1762 ſibi conſtruxerat Wilckius, ex reſina, materia quippe magis apta, confectum, machinae electricae dignitate et Electrophori perpetui nomine donavit. Notandum tamen eſt, tum valde probabile eſſe,

a) Vid. Scripta Academiae Suec. Scientiarum ad ann. 1762.

George Christian Lichtenberg

Concerning the New Method of Investigating the Nature and Movement of Electric Fluid

Preceded by a commentary containing the more general experiments

A Lecture Given at the Public Assembly of the Royal Society for Sciences

February 21st 1778

Among the more remarkable discoveries by which the recent science of Electricity has been enriched, the Electrophore, not at all undeservedly, must be mentioned. I do not at all hesitate to name its inventor, the honourable Mr. Wilcke, our one time fellow citizen and now professor of Physics at Stockholm (a). For the honourable Mr. Volta did not so much discover this machine as an apparatus of instruments, which Wilcke had already built for himself from glass as early as August 1762, in order to prove certain phenomena concerning the Leyden experiments. Volta built his apparatus from resin, a material which is naturally more suitable to the nature of an electric machine and he named it the perpetual Electrophore. But it should be noted that on the one hand it is highly probable that the Italian had never heard of the experiments of the scientist from Stockholm and that on the other hand so great are Volta's merits concerning this instrument that if he is not to be honoured with the name of inventor, he should be honoured however with great praise and honour(b).

This remarkable machine deserves indeed to be mentioned both on account of the phenomena themselves which it demonstrates and on account of the earnestness and zeal of investigating the extraordinary qualities of electric matter which it seems to have instilled once more into physicists, especially the Germans who, as far as this subject of natural science is concerned, for the most part had begun to do nothing or little that was serious or to search again things that had already been sought hundreds

of times.

As soon as I was able to examine the Electrophore it immediately gave me a favourable impression by its prompt performance, its simplicity and its material which is found everywhere and easy to prepare. When I saw that an apparatus 18 digits (1) in diameter produced as great a result as could scarcely be expected from the usual expensive electric machine, I decided to build an Electrophore of noteworthy dimension.

What especially incited me to undertake this and all the more willing was the evident disagreement among my contemporaries over the phenomena which had been revealed to me in that instrument; a disagreement which I believed, not without reason could likely be overcomé, once a greater instrument had been employed. For conducting experiments using instruments of great strength is equal to subjecting the phenomena which the experiments reveal, to the view of a microscope. Phenomena which previously, because of their own tiny appearance, escaped the notice of the eyes and even of the most practiced attention, once they are augmented in this way, they can no longer deceive either the dullest senses or the most negligent and thoughtless observer.

Therefore I took the trouble to build an electrophore, the base of which is a mixture of ordinary resin, turpentine and Burgandy pitch. It has a diameter of six feet, standard Paris measure (2) and the shield or tin conductor is five feet. I observed immediately many phenomena which previously had not at all been visible to me. Yet to a large extent they could in some degree be expected from the great force of the instrument. Thus I am now disregarding these except for a single example which has been included and from which those who have already observed and are familiar with the effects of the ordinary Electrophores, will be able to judge the relative strength of this instrument. I was able to draw forth little sparks (if it is right to so name them, which both by their shape and their effect are like little lightning flashes) fourteen or fifteen digits in length, which passed up through my hand and shook my whole body violently. They were often cast from the disk unexpectedly, causing them to pierce through the base with an extaordinary large noise.

I turn myself now to the principle argument of this text, namely that the phenomenon which was first observed by me, at least in the large Electrophore, I soon discovered could be shown in Electrophores of perhaps the smallest strength. In my opinion this new phenomenon, which is of no small benefit to physical science, once it has been examined by better trained physicists than myself, and ones

who are equipped with larger instruments, I am convinced that it can pave the way to a closer investigation of the nature of electric fluid.

For it happens, and this is not small hindrance to the progress in these inquiries, that electric matter, like magnetic matter, either thoroughly escapes the observation of the eyes, or when it does appear, it is borne with such great speed and, what seems to be beyond a doubt, with such a great accompaniment of particles, that most of the time nothing can be clearly observed except the place and the shape of the spark itself; and this I think is the least significant part of the entire phenomenon. Yet what is surprising about that? For here it is not a question of the fluid, whose rapidity any admirer, rather than a casual observer might compare with the speed of a lightning flash; it is lightning itself which is being observed. Consequently physicists, unable to provide a fixed image of the phenomenon, have at least always endeavoured with utmost care and rightly so to observe its traces. It cannot escape the attention of anyone, not even of someone of modest reading, how the notes of physicists are overflowing with accounts of jars shattered by a stroke of lightning, of metal wire and coins being melted and other such things. But often physicists who are somewhat more fastidious have reported their observations with such painstaking accuracy that, when for example, they give an account of the paths of lightning that has flashed from the top of the chimney into the kitchen and which lasted scarcely a single moment, they fill up notebooks, for which to read through scarcely an hour is sufficient. Furthermore the spots which have been produced on polished surfaces from the explosions in Leyden jars and the little holes they pierce through paper, have been considered worthy of the attention of the greatest physicists. Among the very well known discoveries and recent observations of the honourable Mr. Priestley, the observation of little rings, which he produced on polished metal plates by striking them with a shock from his own large electric machine, does not occupy the place of least importance.

I am convinced that the experiments which I am about to submit to your scrutiny, my esteemed friends and listeners, surpass those which have just been mentioned, both by their beauty and variety of their application. By their beauty because, although they are not related to the class of clear electric phenomena, they nevertheless could compete with these same clear phenomena, just as (which is not a scant recomendation) I have no doubt that impostors (3) will at some time assign a place for my little machine somewhere between a calculation device and their own devices of trickery. I say by the variety of their application because in the first place they present to the

learned man an easy method of observing the nature of this fluid which is similar to the method by which they examine the movement of magnetic fluid, that is by scattering around filings of magnetic iron; and in the second place because they reveal the mutations which are taking place in bodies charged with electricity, and especially idio-electric bodies, mutations which were hitherto unknown to physicists. I say nothing about their use, but this will stand out clearly in the explanations of the other phenomena of nature.

The occasion of observing this phenomenon was the following. At the beginning of spring 1777, after the completion of the new Electrophore, everything in my little room was still covered with extremely fine resinous dust that had settled, between the scraping and the shaving of the instrument's base or stand, on the walls and books. As soon as a draft in the air arose, the dust often fell, much to my annoyance, on the conducting disc of the Electrophore. Often afterwards, when I held the disc suspended from the ceiling of my room, it turned out that the dust, as it settled on the base, did not cover it completely, as it previously had covered the disc, but only in certain areas. Much to my great joy, it gathered to form little stars, dim and pale at first, but as the dust was more abundantly and energetically scattered, there were very beautiful and definite figures, not unlike an engraved design. Sometimes there appeared almost innumerable stars, milky ways and great suns. There were arcs, unclear on their concave side, but radiant on their convex side. Very glittering little twigs were formed, similar to those which frozen moisture produces on glass window panes. There were clouds of different shape and shadows that were visible in varying degrees. Finally there were other figures of particular shape, only one of which is contained in Table 1, along with the little stars. But the most pleasing sight presented itself to me, when I saw that these figures could not be easily erased, as I tried to wipe away the dust with a feather or a rabbit foot. I could not prevent these same figures, which I had just erased, from shining forth once more, and somehow, more brightly. Therefore I placed a piece of black paper smeared with a viscous material on the figures and pressed down lightly. I was able to produce imprints of the figures, six of which the Royal Society has seen. This new kind of typography has been extremely satisfying to me, hastening as I was to more remote preocupations and having neither the time nor the inclination of sketching the figures or destroying them all.

All the figures, about which I have spoken so far, were somehow produced due to chance in the Electrophore, or at least the method of production was at that time utterly

unknown to me. For I raised the disc, scattered resinous dust on the base and whatever star then appeared was due to fate alone, which began immediately to attribute its gifts with a more sparing hand. For when I noticed that the scattered dust and the figures themselves were considerably decreasing the strength of the Electrophore, I had to wipe it off more frequently and strengthen it with new rubbing, whereby the figures were at once completely destroyed. Therefore I became tired of this precarious procedure and of playing with the experiments and as soon as the pleasure of observing this new phenomenon had waned, I began to consider more carefully the experiments already performed and to examine more closely the ones being presently conducted. Then there came to my mind the recollection of the loud noise from that part of the Electrophore which, after the dust had been scattered, abounded most with the little stars and where the noise was likely produced. It made me think that the figures had arisen due to either the passage of the electric material of the positively charged disc through the resin of the base and into the lower lining or due to the charge on the surface. I was soon convinced of this when I set up my experiments at night. As a very fine luminous current (4) passed from the disc to the base, I finally noticed that these little stars were projections of this current. I also discovered that the electricity of the base was positive in that part and that after the disc had been slightly raised and brought nearer it was negatively charged. This new and quite extensive field of experimentation which had been opened up gave me new inspiration. Therefore I first placed little round pieces of tinfoil on the Electrophore which were slightly attracted by the raised disc and afterwards fell to the base and moved around it with a rotating motion marking their path with the most shining twigs; the pointed ends of instruments for instance compasses, which had been placed there, were surrounded by coronas and radiant aureoles. Metal tubes which had polished little globes at the end, and which had been placed on the base produced suns. Once the cause of the phenomenon had been discovered, I began to use smaller Electrophores, on which all the experiments may be easily performed by anyone with little effort and little expense. But so that they may be performed more easily and without false trials, I shall describe my apparatus briefly, especially the construction of my double Electrophore, which is as suitable to these experiments as to many others.

Cover a plank of wood, Linden wood for example, (Table IV, Fig. 1) which is oblong in shape about 2 feet long, 1 foot wide and 1 digit thick with either tinfoil or gold paper, so that the thickness of the plank may be covered. Next gird around the edge a plank of pliable wood which

projects above the covered surface 2 ; .ines and which may be fixed with at least one or two nails. Into this tray (for it is a question of its shape here) pour carefully as much of the mixtures, prepared as specified from ordinary resin and Burgundy pitch, as it will take. Make sure to add a small measure of turpentine so that the resin can be made more viscous and may yield more easily without disintegrating to the changes brought about by the air temperature on the plank.

When this has been completed, construct a circular disc .. digits in diameter from either tin or wood or cardboard covered with tin foil and equip it with metal wires fig. 2). I took the trouble to build mine from Linden wood. Before it is covered with tin, stretch out across the hollowed underside either a parchment or piece of .inen or heavy paper (a-b fig. 3) (5) by which contact with the resinous surface of the Electrophore is made more perfect and smoother. This disc may be placed in either position P or N of the Electrophore so that it .s one digit from the belt around the edge, and so that either of the circles which it occupies are two digits apart.

The method, which I use in charging the Electrophore, is scarcely less simple than efficacious and it is worthy of the attention of physicists. Let us suppose that the Electrophore is completely lacking in electricity. Then using gentle friction, rub with the dry hand or a down feather, taken from a quill pen and rolled up into a ba.., that part of the electrophore P, from which you wish to charge the disc with positive electricity which I shal. always designate by the symbol +E fig . Then place the disc in P and after communication had been establishe- between it and a nail of the belt around the edge, by touching one with the thumb and the other with the middle finger, lift the disc with the right hand by means of the metal wires. Its quantity of +E, however little it may be, will flow into the little tube or any metallic body located in position N. Then move the tube a little with a finger or whatever other idio-electric body is at hand such as a quill pen or a stick of sealing wax and repeat as previously. Once this operation, which always imparts the +E of the disc into the tube placed in position N, has been repeated three or four times, and before a new charge is prepared, change the position. Place the little tube in position P and the disc in N, after which it has been raised, will be -E. Let the tube which is now placed with.n P, be charged with the -E. Furthermore by alternating the postions several times, and by placing the tube and the disc at one time in this position and at another in the opposite position, you will find side P largely +E, and side N, naturally -E communicating with the disc that has been placed there. In this way I saw the Electrophore with

tiny sparks in P scarcely larger than a grain of gun powder, and none in N clearly communicating with the disc and within four minutes it was so charged by its own force that the disc was producing sparks of +E and -E 12 digits in length. If the disc were placed in position N and P of the Electrophore so that the parts of the circles would be covered by it in inverse ratio to the electrical strengths they possess after it was raised, it would produce no electricity. But the electricity of the disc touching equal parts, after the disc has been raised, will be equivalent to the sum of the electricities of the circles N and P.

Once these things have been prepared in this way, it will be possible for anyone to perform the following experiments with utmost ease. Have at hand also a few thin plates produced from either gum-lac or ordinary resin. Equally suitable are plates produced from colored sulphur or sealing wax and plates of colored glass 6. Keep also at hand different kinds of tubes, some ending in polished balls, some ending in very sharp points: some resinous, sulphur or crystalline dust wrapped up in linen cloth, and a Leyden jar equipped with a conducting chain.

EXPERIMENT I

Place the tube equipped with a polished ball at the end on the plate of gum-lac or ordinary resin (Tab. IV Fig. 4). Give it a charge of +E and after it has been moved by the bare hand and dust has been scattered around, this radiant sun will appear which table II contains. But when the tube is moved by means of an idio-electric body, the little black circle, which is the base of the radiance, will disappear.

EXPERIMENT II

Let the tube be charged with -E. Afterwards, when it is moved with the bare hand, it produces the figure which we have reproduced in Table III. The tube moved with an idio-electric body produced a different figure, almost devoid of these little twigs. It must be noted here that after I had already sketched the figure of Table II, I often saw figures produced from positive electricity and surrounded by two or three concentric circles. But since it is my intention not so much as to indicate what I have seen, but what others must do, so that they themselves may see, I have reserved my conjectures for someone else to comment on and I did not want to make more etchings.

EXPERIMENT III

Place the plate of gum-lac on a shorter tube and set the other tube as before on the plate in the manner indicated by Figure 5 Table IV. A +E imparted through point A will produce a radiant figure on the other side of the plate, but a -E will produce one lacking in rays on the other side and a little different from those etched here. But even the least practiced eye will easily see their similarity. In the same way electricity can be made to go through several resinous plates at once and its route can be followed. The exact opposite will come about if, instead of +E, a -E charge is given.

EXPERIMENT IV

Place the Leyden jar on the resinous plate and charge its hook with +E, and the figure produced on the plate will be of the positive kind. On the other hand, if the hook is charged with -E, it will be of the negative kind. The attentive observer will see many things here. I saw very bright little rings, elliptical spots and circles in which, when they were moved closer to the eye, I saw ellipses and concentric circles marked by very fine lines on the surface itself of the dust. I obtained the most elegant figures of this kind, whose marvelous formation and regularity I cannot express in words, by placing a glass cup (an ordinary beer glass) uncovered on the outside and filled with water on the plate of gum-lac and by charging the water with +E and -E through the tube so often mentioned fig. 6 .

EXPERIMENT V

Now we may announce the new type of stenography which I fell upon by chance and which will offer a most pleasing sight of the pleasures which the contemplation of nature provides: pleasures which may be enjoyed by anyone who is not utterly dull. Fill completely with a charge of +E a Leyden jar which has lining on the inside and the out, and is equipped with a pointed conductor and a chain fig. 7 . Then with one hand bring the conducting chain close to a nail of the belt, and with the other hand grasp the outside lining of the jar. With the conductor C make different paths on the surface of the Leyden jar. After the dust has been scattered, or even after an interval of several days, these paths will appear most brightly not at all unlike the garlands of plants. If on the contrary, after the jar has been isulated, the pointed conductor at the top of the jar is applied to the nail, and the paths are made by the chain, they will appear similar to lines of pearls.

At this time, I have neither the time to include more experiments nor do I think they are necessary for our purpose. I shall add only one, which should be separated from the rest, because up to now, it has only succeeded for me twice. For this it cannot very well depend on the general causes. I placed a few drops of water on the surface of the big Electrophore, as much as was necessary to form a circle of water 1 digit in diameter, and I set the tube in the middle of this circle and then infused it with +E. After the dust was scattered, the water always began to be surrounded by an atmosphere (7), which however, in the cases just mentioned was imperfect. For the ellipse formed at "a" failed to perform as usually and repelled the dust. (Tab. IV fig. 9) and in its place beyond the atmosphere another greater ellipse "A" was formed. The cause of this phenomenon is still a secret to me, but it is likely that there was a hidden conductor between "a" and "A". In the meantime those attempting these experiments will see an abundance of similar phenomena, the explanations of which cannot but advance the theory of electricity. Now I shall add the following precautions and observations.

(1) Glass plates substituted for the resinous plates are satisfactory up to a point, but the figures rarely appear as bright and distinct. Sometimes I used playing cards, elastic gum, linden wood, etc. with varying effects and success.

(2) It is necessary to wipe the plates well because the figures do not allow themselves to be easily erased and in using the same plate, one might attribute to one cause that which is the effect of several. But once the dust has been wiped off, the later effect of the earlier electricity may be erased easily and completely by a single breath.

(3) The dust which is to be used in the scattering must be very fine sulphur or resinous dust and wrapped in linen cloth, and the metal filings must also be extremely fine.

(4) It would perhaps be useful to repeat similar experiments under a bell.

(5) I scattered the iron filings on a resinous plate placed on a magnet, but I could not observe anything very special.

(6) Tubes equipped with points are much more suitable than others for producing concentric circles.

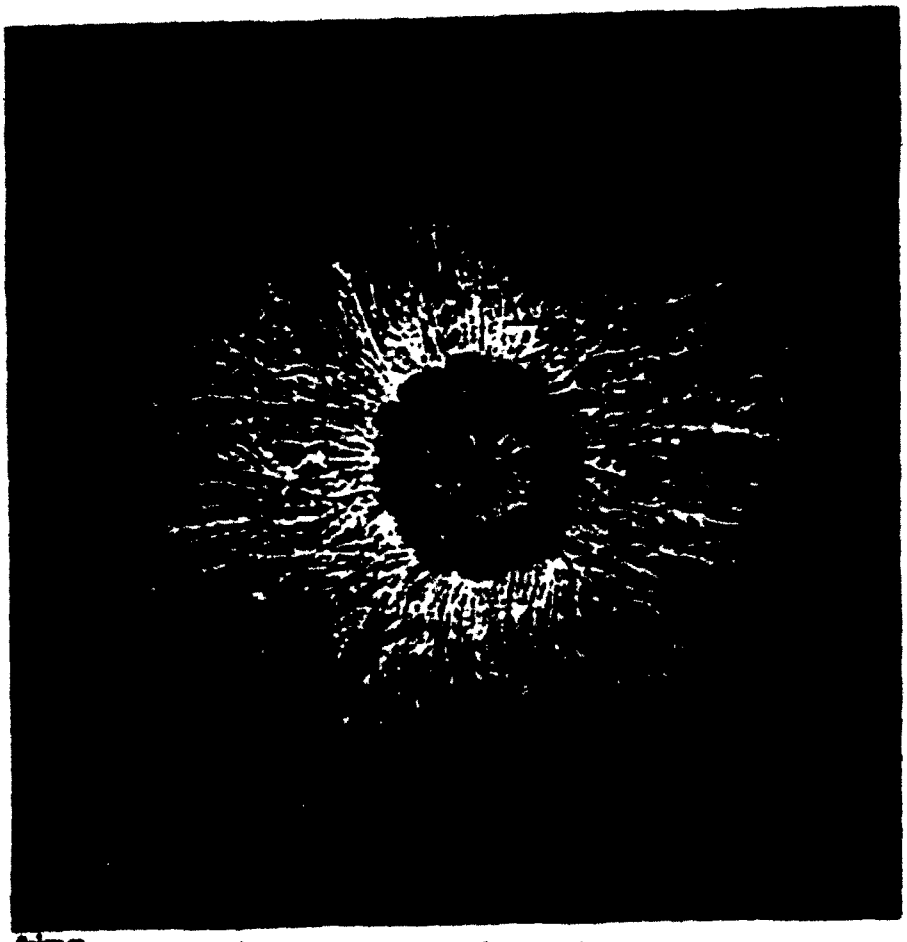
(7) It is necessary to place the resinous plates in the preceding experiments on conducting or anelectric bodies.

(8) The concentric circles and little circles which one meets everywhere in these experiments shed considerable light on the ingenious theories of the honourable Mr. Wilcke (c) and also in fact on the explanation of electric pauses of Mr. Grossius (d), about which I hope to say more in the future.

Tab. I.

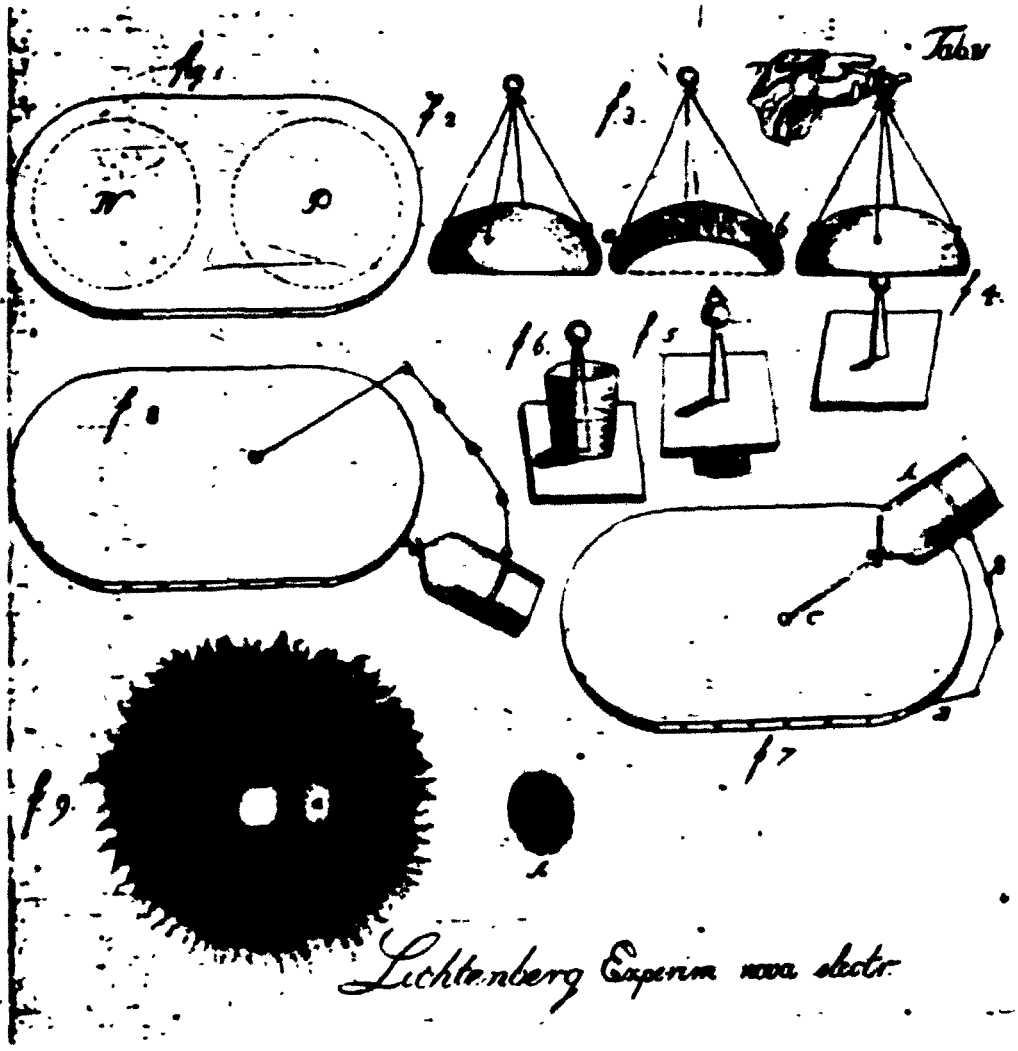
Lichtenberg nova Exp: electrica.

Fig. II.



Lichtenberg nova Exp. electrica.

Lichtenberg novi Exp electrici.


Tabv
f1
f2
f3
f4
f5
f6
f7
f8
f9
Lichtenberg Experim nova electr

AUTHORS NOTES

a) See Scripta Academiae Suec. Scientiarum as ann. 1762

b) As only the name is unique, the honourable Volta discovered a most ingenious method of increasing the strength of the Electrophore to almost any degree. No other such electric machine has yet been produced.

c) Kongl. Vetenikaps Acad. Handlingar for Ar 1777

d) Electriche Pusen. Leipzig 1776. Rozier, Observations sur la Physique, Septembre 1777, p. 233

TRANSLATORS NOTES

(1) 1 digit = 0.727 inches

(2) The standard Paris foot is equal to 0.324 meters

(3) The work used for imposter is juggler, and for devices of trickery, the goblets used by jugglers to catch their pebbles or the objects being juggled. The implication being that Lichtenberg suspects that he will be accused of sham.

(4) The Latin text does not speak of a current but of luminous penicillis. A penicillus is a fine painters brush or hair pencil which might suggest very fine line, and so I am extrapolating by speaking of a current. The French text uses the word aigrette, which is a fine spray or feathery tuft. In both cases, however, I feel it is a question of the continuous transmission of very fine visible electricity.

(5) The Latin text says stretch on the hollowed inferior side. However the French text on the concave side.

(6) The plates of gum-lac, sulphur and resin are actully called tabulae which may be either boards or planks. The French translation speaks of cakes of gum-lac, resin, sulphur or wax. They may also be tablets, as in wax tablets.

(7) The atmosphere is a supposed field surrounding and influencing bodies cf. magnetic atmosphere.