'ELECTRIC SHOCKS.

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I bring this question before the Institution principally with a view of obtaining particulars of severe electric shocks which have not proved fatal ; and therefore trust that any one who, from his own experience, can give particulars of cases, will kindly do so. My reason for trying to obtain this information is that I believe we, as electrical engineers, can render great assistance to the medical profession by doing so ; and possibly by enabling them to tell us some better methods of rendering aid to those who, unfortunately, are the victims of accidents, we shall be well repaid.

I have been personally deeply interested in this subject for some years, and have collected from my own experience and that of friends both in this country and abroad, particulars of as many cases as possible. I have also, whenever I could, made it a rule to see the man who received the shock, and also any witnesses. All cases, therefore, which I have chosen as of sufficient importance to mention in this paper are, to the best of my belief, thoroughly accurate and reliable. In obtaining this information I have been much struck by the fact that it is most difficult to obtain a really accurate description from the victim or witnesses of what actually does occur, and this can hardly be expected when one considers the circumstances ; but still, if I only mention what they are absolutely certain about, these cases can be taken as fairly typical.

I should like to say that, not being a doctor, I have no medical knowledge, and therefore trust that any medical men reading this paper will take this into account if I say anything which to them may seem absurd.

In discussing this question with my personal friends in the electrical profession I find there are many points upon which more information is required, and I think these points may be best summarised as follows :—

1. Is every one equally susceptible to an electric shock ?
2. Is a person suffering from disease more liable to be

fatally injured by an electric shock than a person in good health ?

3. Does the physiological condition you are in at the time you receive a shock make any difference ?
4. Does the path which the current takes through the body have any effect as regards the shock proving fatal ?
5. Does the question of contact made, and whether burning takes place or not, have any effect as regards the shock being fatal ?
6. Can a person receive a fatal shock without giving the cry, and also can he speak after receiving a fatal shock ?
7. Is an alternating or a direct-current shock more likely to prove fatal ?
8. Cannot the Medical Profession give us some more certain method of saying whether a man is dead or not ?
9. Cannot something more be done than at present to help those who receive a severe shock ?

I will now proceed to discuss these points separately.

1. *Is every one equally susceptible to an electric shock ?*

In considering this question, I believe I am stating the opinion of the medical profession when I say that there is no absolutely reliable proof whether every one is equally susceptible or not. Dr. Oliver, in Allbutt's *System of Medicine*, vol. v., page 856, says : "We have no positive proof that one individual is more susceptible to an electric shock than another. It is, as already stated, rather a question of the amount of current, and whether it wholly enters the body."

My own opinion is, and I hope to prove it in this paper, that not only are different people differently affected, but the same person under different conditions does not feel the same. Of course, if one could obtain two people alike in every respect and subject both of them to exactly the same voltage and current, and also in every respect get the same conditions, no doubt they would both feel the same, although they might describe it differently ; but when it is considered that moistness, callosity, and condition of skin, nervous

temperament, the path which the current takes through the body, health or disease, drunkenness or sobriety, whether the sufferer is awake or asleep, area, the excellence and nature of contact, familiarity with shock, and no doubt other causes, as I shall point out later on, all play most probably an important part in deciding what one feels, I think my opinion will be accepted.

2. *Is a person suffering from disease more likely to be fatally injured by an electric shock than a person in good health?*

As an electrical engineer this is a most difficult matter for me to discuss; but from cases which have come under my own observation, and which I have heard of from friends, in whose veracity I can place the most implicit confidence, I think I can prove that this question is of the utmost importance. Some years ago a number of friends were in the habit of measuring their resistance periodically, and it was found that one man was always the lowest, although they all varied. This man was also abnormally sensitive to an electric shock, as he could feel even so low a voltage as that from three Leclanché cells. It was afterwards found that he was suffering from kidney disease, and although I should very much like to measure the resistance of others similarly affected, I am afraid to do so in case I might injure them. This seems to indicate that the resistance of the body may be altered by disease, and it is most probable that the skin, by fulfilling the functions which by rights belong to the kidneys, had a lower resistance due to the impurities thus removed from the body. (It is well known that in kidney disease the doctors give medicine to make the skin help the kidneys.)

In a central station I was connected with, it was the habit of the men to give an electric shock from a magneto-machine to visitors, and although it was found that different people seemed to feel differently, yet one boy could stand more than any one else. He was, however, unfortunately of weak intellect. Another case of which I have heard was at a bazaar, where money was placed in a bowl of water charged from a Ruhmkorff coil. One woman took the money out every time, and had to be paid to go away as she nearly made them bankrupt. She also was of weak intellect. No doubt this insensibility was due to the brain being affected.

It appears, therefore, fair to say that a diseased person may be either more or less susceptible according to the disease he may be suffering from.

3. *Does the physiological condition one is in at the time a shock is received make any difference?*

The first point which naturally occurs to one is, does a person in a heavy perspiration stand a better chance than one who is in a normal condition? and to illustrate this, I think I may quote the following case :—

“T.” had been doing very heavy work which made him perspire freely; to rest himself he sat down on a transformer, which was earthed, and in leaning back his head touched an inner terminal; as the outer was earthed he received a 2,000-volt shock. The man was wearing a thick flannel shirt, which was wet with perspiration. The result was that he received a most severe shock, a hole being burnt in his trousers, and the back of his head and buttocks were severely burnt. This man, I think, should have been killed, but he was not even insensible. Surely this seems to show that the sweat shunted the current, thus saving his life; although the burning probably protected him, as I will show later on.

Again, would a man, when drunk, be less liable to be fatally injured? and to illustrate this I give the following case :—

“F.” was working in a transformer station as a labourer, and touched an inner terminal with one hand and an outer with the other, the potential difference being 2,000 volts. It was found out afterwards that the man was a heavy drinker, and was under the influence of drink when he received the shock, which did not even make him insensible. It is only fair, however, to state that his hands were exceptionally callous, due to the fact that he had been working as a gas stoker, and also that his hands were severely burnt. Personally, however, I think the man received quite enough to kill him, and his being drunk had something to do with his not being killed.

Next, are persons less liable to be killed when they are asleep?

Some years ago I was carrying out a contract which necessitated all the work being done at night. One of the men employed was always going to sleep, so the other men

as a practical joke gave him a shock, whilst he was in this condition, from a magneto - machine capable of ringing through 30,000 ohms., but although they tried all they could he did not wake. As they thought this was peculiar the men called my attention to it, and I personally saw him receive a shock without taking any notice of it. I may also say that I arranged for my assistant to give me a shock when I was in bed asleep, and although two witnesses guaranteed he had done so, I felt nothing. Illustrating this, I should like to mention the following case :—

“B.” was stationed to watch a cable under test charged to 5,000 volts, and going to sleep fell on to it. He was most severely burnt about hands, but was not killed.

Of course, with so few cases it is impossible for me to say that my deductions are absolutely correct, but I bring them forward as I think they are of profound interest both to the electrical and medical professions.

4. *Does the path which the current takes through the body have any effect as regards the shock proving fatal ?*

Although I have been present in three cases where a doctor was called in to attend to a man who had received a severe shock, I have never been asked where the current entered and left the body, and this, to me, has always been a complete puzzle, as amongst all electrical engineers I know it is a firm belief that the path which the current takes is of the utmost importance, and therefore in handling high-tension apparatus we always try to make contact in such a way that no vital part is directly in the circuit.

To illustrate the different paths the current can take I will give a few cases which have come under my notice, and also what the victim felt most :—

Hand to hand	Blow in chest.
Right hand to right foot ...	Nothing.
Right hand to left foot ...	Nothing.
Right hand to both feet ...	Nothing.
Left hand to left foot ...	Blow in back of neck.
Left hand to right foot ...	Blow in back.
Left hand to head	Blow on top of head.
Head to buttocks	Could not ascertain if anything was felt.

Of course I cannot say why they should feel differently, but I bring these facts forward, as perhaps the doctors can give an explanation. I think, however, it proves that different organs of the body are affected. Dealing with this from actual cases :—

“D.” was oiling an alternator, and touched the inner brush accidentally with his elbow ; his right foot was on the earthed frame of machine, and his left foot insulated. The pressure was 2,200 volts, and although he gave the cry, and was sensible till the circuit was broken, he could not get away. He remembered them running to shut the machine down, but became insensible when this was done, and was treated for forty minutes by artificial respiration before he showed any signs of life. One would have expected this man to be killed, but it is only fair to say that he was badly burnt on the elbow and the foot.

“J.” was adjusting an arc lamp. He had his left foot earthed, and with his left hand touched the carbons. I am unable to state the number of volts that he received, as I could not ascertain where the current earthed ; but he was killed. There was only a slight discoloration noticeable, and he was not burnt.

I will discuss the question of burning later on, but I think it is a fair conclusion that the left side is more vulnerable, and I believe the reason is that the valves of the heart on this side are more easily damaged.

To my mind these cases prove conclusively that the path the current takes is a most important factor.

5. *Does the question of contact made, and whether burning takes place or not, have any effect upon a person's chance of being killed ?*

In my opinion the question of contact is perhaps the most important of any which occur when a person receives a shock, and I should like to go into it rather minutely. In our ordinary every-day work perhaps the question of contact receives more attention than anything else, as not only is it a question of good contact, but the area of contact must be sufficient to carry the current. Now, when a man receives a shock this is equally true, and although it might be safe under ordinary conditions to work with even a high

voltage, yet if he really did his best to kill himself he could most probably manage it with even a small voltage, provided he had a sufficient area of contact.

To illustrate what an important part this area of contact plays, I had my resistance measured holding a No. 20 B.W.G. copper wire between the finger and thumb of each hand, and afterwards I connected these two wires to two pennies, and held them in the same way. With the pennies my resistance was 20,000 ohms lower. I therefore think if the area of contact were only sufficiently large, the resistance would be practically nothing. Of course, if the skin were wet, the area necessary to get no resistance would be much less, but as one does not work with wet hands, I need not consider the question. On the other hand, if the skin were oily it would be much more.

Another point on which I would lay particular stress, is that the area of contact to get the same resistance in different persons would not be the same, and even with the same person in different parts of the body the area of contact would have to be changed. To illustrate this I measured the resistance of six people, picked haphazard, from thumb to thumb, and although I was careful to obtain what I believe was the same amount of contact in each case, yet—

A	measured	30,000	ohms.
B	"	50,000	"
C	"	60,000	"
D	"	60,000	"
E	"	100,000	"
F	"	over 100,000	"

this being due most probably to different thickness and moistness of the skin. As regards the same person, I had my resistance measured from thumb to thumb, which gave 100,000 ohms, but from heel, where the boot rubs, to big toe, I got 200,000 ohms, although in each case I believe the same contact was made.

The question of area of contact also plays an important part from another cause, as, if the area is small, the chance of burning is largely increased, not only from the fact that heat is generated at a bad contact, but that it is easier to form an arc, which causes the burning to be still more

severe. I shall discuss the question of burns by alternating- and direct-current later on, but a direct-current burns much more severely, especially at the positive pole.

No doubt it may be questioned why I am laying so much stress upon a point which is thoroughly understood by every one, but my reason for doing so is that I believe this question of burning is a wonderful provision of nature to protect us against fatal shocks, as the burning not only numbs the nerves, and thus prevents us feeling, but will also, I believe, be found to increase the resistance, thus preventing the current passing. It is impossible for me to experiment on burnt live flesh, but I think it would well repay a doctor to do so.

Taking actual cases :—

“C.” was working on a high-tension switchboard and received a 2,000-volt alternating shock. The man was killed. I myself saw the body, and noticed that there was only a slight burn on the left hand, no other mark being found on the body. It was therefore impossible to say how the man really received the shock. I am sure the burn was only slight, and as I have had considerable experience of electrical burns at various voltages (both alternating and direct), I think I am in a position to judge as to their severity.

“F.” received a 2,000-volt alternating shock from hand to hand. Death occurred. The engineer-on-watch at the time told me that only slight burns were on each hand.

In the case mentioned of a man killed on an arc circuit, only a slight redness was seen on his hand. Of course, this may not always be the case, as it is quite possible that the victim in his struggles to escape may reduce the contact and therefore cause severe burning after he had received sufficient current to kill him. In previous cases I have mentioned where the victim recovered, severe burning took place, and I shall mention more later on.

I know I am laying myself open to severe criticism in bringing forward this theory, as the majority of electrical engineers, and also the doctors, believe that severe burning means a severe shock, and to illustrate this I cannot do better than again quote Dr. Oliver in Allbutt's *System of Medicine*, page 857, where he says : “ If the skin at the time of contact was moist, so much more the burning. If a

current sufficient to produce this severe local burning pass through the body, fatal results are more probable." My own opinion is, however, from reasons stated above, that moistness of the skin reduces the chance of burning as it ensures better contact, and if no burning takes place, efforts to help the victim should be redoubled if it is thought that he has received a shock, as it is quite possible that, owing to this misapprehension, he may be thought to be ill from some other cause.

I should like to say a good deal more on this question, but as the time is short will proceed to the next point.

6. *Can a person receive a fatal shock without giving the cry, and also can he speak after receiving a fatal shock ?*

It may be of interest to attempt to describe the cry, and as I have heard it three times, and have discussed this matter with others who have heard it, I think it can be accepted that this cry is best described as a rapid drawing in of the breath, followed by a half sigh, half shriek. In each of at least a dozen cases of more or less severe shocks that have been reported to me the victim gave the cry, but in the case in which I personally saw the victim three witnesses were sure that he did not give the cry.

With respect to the question as to whether a person can speak after he has received a fatal shock, I may say that I have always thought this impossible ; but in the above case the victim was asked if he was hurt, and he said, "I am all right," and yet directly afterwards dropped down dead. Of course one may ask, did he really die from an electric shock ? but as a post mortem was made, and the doctor satisfied himself that all the organs were healthy, I think there can be no doubt about it.

I think, therefore, that further information is most urgently required ; but at present one can only say that a man need not give the cry, and that it is possible for him to speak after a fatal shock has been received.

7. *Is an alternating or a direct-current shock more likely to prove fatal ?*

This question may be looked at from two points of view :—

First : If a man is killed by an alternating shock, would not a direct-current shock prove equally fatal, provided the conditions in each case were exactly the same ?

Secondly : Is there anything in the actual working conditions which makes one supply more dangerous than the other ?

Considering this from the first point of view, the question immediately occurs : Do both kinds of shock affect the body in the same manner from a medical standpoint ? Of course I am not in a position to judge, but as a direct-current causes electrolytic action, and an alternating-current does not, it seems that more must take place with direct-current than with alternating-current. My attention has been called to the fact that under certain conditions alternating-currents will cause electrolytic action. Any information on this point would therefore be valuable.

It is also open to discussion whether, disregarding electrolytic action, the two act the same, as the alternating from its nature must have a spasmodic effect, whilst a direct-current seems to paralyse at once. From my own experience of shocks, I am certain that the after-effect of a direct-current is worse than that of an alternating current.

When looking at the matter, however, from an electrician's point of view, I can see a great difference, as there is no doubt that if contact is made with metal of such a shape that it cannot be gripped, and the current passes from hand to hand, the direct-current seems to knock the victim down, whilst an alternating-current seems to draw him closer and to tie his body as far as possible into a knot. On the other hand, if he can grip the metal, the direct-current seems to hold him tighter than does the alternating-current. Of course I am only judging from what I have seen and felt myself.

Another influence which I believe plays an important part is the different action which the two currents have in breaking down a fault. For instance, if the insulation is faulty when current once commences to pass, the direct-current will break a fault down more quickly than will an alternating-current. No doubt this has some effect when a shock is received, as most probably the direct-current would reach its maximum before the alternating-current, and,

therefore, if a person is only in circuit for a short time, the direct-current would have the greatest effect. On the other hand, more burning will take place with direct-current than with alternating-current, and as I have pointed out before, this is most probably a protection.

My own opinion is that both currents will kill a man equally well, provided that the conditions are the same, and that death ensues from an electric shock.

Although not strictly included in this paper, I should like to draw attention to the fact that an arc is more easily started with direct-current than with alternating-current, and that when once started it is more easily maintained. This is evident from the fact that a fuse which is quite safe on alternating-current is utterly useless on direct-current circuits. From the above cause it is possible for a man to be severely burnt on continuous-current, and therefore all cases of exceptionally severe burning, if they occur on a low-tension supply, should be thoroughly investigated to prove whether death occurred from a shock due to burns or to an electric shock.

The conclusion I come to is, that if death occurs from an electric shock, both are equally dangerous; but if death occurs from burns, the continuous-current is more dangerous. To make myself thoroughly clear, I should also like to say that although burns are a protection against electric shocks, yet if carried to extremes they may themselves cause death due to shock.

In considering the second question, it must be remembered that although the majority of deaths from electric shocks occur with alternating-currents, yet the potential usually worked at with alternating- is higher than that with direct-current, and therefore the conditions required to cause death have to be more favourable with direct-current than with alternating-current.

Taking the actual voltage required to cause death, independent of nature of supply, I should say :—

At below 600 volts the conditions must be abnormally favourable.

At below 1,000 volts the conditions must be favourable.

At above 1,000 volts the higher the pressure the more

easy it is to get the conditions necessary to cause death.

In comparing the relative dangers of the two sources of supply, it must be remembered that even with the same voltage and conditions, it is quite possible to meet with an accident from quite different causes due to the kind of supply. For instance, with an alternating supply where the outer is earthed, nine times out of ten a shock is received not by getting into the circuit proper, but by touching some metal which has become charged owing to its not being properly earthed, or to not realising that any earthed metal is practically the outer. I think, however, that accidents from this cause will be fewer in the future now that the precautions required are thoroughly understood, and, more important still, that we are able to obtain trained men.

On the other hand, with direct-current, most accidents occur due to an earth on circuit causing a man to receive a shock when he accidentally earths the circuit in another place through himself.

The conclusion I come to is that there is nothing more dangerous in one system than in another. It is purely a question of voltage and of the conditions being favourable, and it must be remarked that as many conditions have to be favourable, it is really so difficult to get killed, even with a high voltage, that practically, with our present knowledge, the chance of this occurring is no greater than in numerous other occupations where a person is likely to meet with an accident.

8. *Cannot the Medical Profession give us a more certain method of ascertaining whether a man is dead or not?*

In the *Electrical Review* Rules, which I consider most excellent and indeed invaluable, it is recommended to ascertain if the sphincter muscle is relaxed; but as this is for obvious reasons objectionable, and also to a non-medical man most difficult to judge, I ask the doctors if they can tell us some better method. If they only knew what one feels when, after doing all one knows to restore a fellow-worker to

consciousness, the question arises, Am I simply manipulating a dead body? I feel sure they would do all they could to tell us how to arrive at a definite conclusion.

9. *Cannot something more be done to help those who receive a shock?*

In discussing this question, the first thing which strikes me is how utterly we engineers are in the dark as to what really happens to a human body when death is caused by electricity.

Of course, death is a stoppage of the functions of the body; and looked at from an engineering point of view, I think the organs of the body can be best described as follows, namely, the lungs as the boiler, the heart as a pump, and the nervous system as mains to transmit signals from the controlling power (the brain) to the various machinery operated, and the arteries and veins as feed-pipes. Now, to my mind, what we want to know is, what breaks down when a shock is received? Are the lungs so damaged that they are useless for further work? or is the pump, the heart, broken in any way that it cannot work,—for instance, are the valves ruptured or the arteries, viz. the feed-pipes, broken? or is the blood, the feed water, so decomposed that it precipitates and chokes the pipes? or cannot signals be sent from the brain, owing to the nerves being paralysed? or what happens?

Looked at from this point of view, the first thing which requires clearing up is, are the conditions found inside the body different when death has been caused by electricity to those found when it occurs from shock from fright, excitement, burns, amputation of a limb, etc. Of course I, personally, cannot say, but from medical evidence which I have read it appears as if the only thing which is unusual is that the blood appears different at post mortem; but I believe this is open to discussion.

I, myself, think, however, that when it is considered, as I have pointed out previously, that an idiot does not seem to feel a shock so severely as an ordinary person, and also that during sleep less is felt, the truth will probably be found to be that electricity acts like an anæsthetic, such as chloroform. My reasons for believing this are also due to the fact that in two cases of an electric shock where death would have

been expected, the men recovered, in my opinion, from the head being lowered, thus flushing the brain with blood, which is exactly what the doctors do when they want to revive a patient who has collapsed when under chloroform.

The cases referred to are as follows :—

“B.” received a 2,000-volt shock from hand to hand, but was not badly burnt. He was insensible : we could not feel his heart beating, and his breath did not cloud a mirror ; his eyes were turned so that we could see only the white of the eyes, his jaw was dropped, and thus seeing the man I could have been certain that he was dead. This man gave the cry, and an engine-driver who picked him up stood him on his head, and thumped his chest, his reason being, as he put it, to start the blood flowing, and, as the heart is a pump, to free the valves if they were stuck. After forty-five minutes’ artificial respiration this man recovered.

“T.” received a 2,000-volt shock from hand to hand. He was standing on a pair of steps. As no one was present I cannot say if he gave the cry, but at any rate he fell head first off the steps about four feet to the floor. He came round without assistance in about twenty-five minutes. It is only fair to say that his hands were badly burnt.

The question, therefore, which I wish to ask the medical profession is, should we adopt the same treatment as is used for collapse from chloroform, and when a man receives a shock should we, before applying artificial respiration, hold the body for a few seconds head downwards at an angle of 45 deg., thus flushing the brain and stimulating its action ? I bring this theory forward with the greatest diffidence, but as I have actual cases to bear me out and also other evidence which points the same way, I think that considering its vital importance to humanity, I am justified in doing so in the hope of its being investigated by the medical profession ; but until this has been done, no one realises better than myself that my evidence cannot be considered as conclusive.

In conclusion, I can only say that I am fully aware of the shortcomings of this paper, but it is a real attempt possibly to save a human life by thus endeavouring to get members to give information on this question which so immediately concerns us as electrical engineers.