Quantitative Hazard Assessment of the Human Body due to Electric Shock in Water

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1. INTRODUCTION

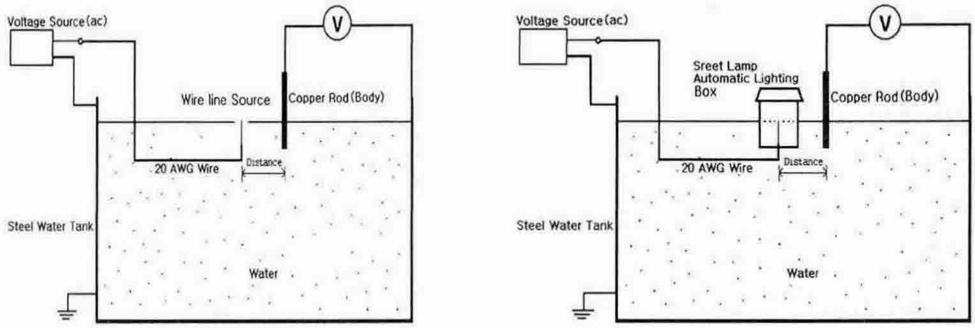
Many Submerged electric facilities in a localized torrential downpour may create a shock hazard for the human body, since wet skin coming in contact with intentionally or accidentally energized parts can result in a part of low electrical resistance through the human body for leakage or fault currents. Also a satisfactory separation can't be offered for absence of safety guard. A person in rainwater by the submerged electric facility will receive electric shock by three methods[1,2].

1) The person can directly contact an energized metal part, while simultaneously contacting a metallic or otherwise conductive surface that has a different potential. This situation is quite similar to the usual hand-to-hand or hand-to-foot shock hazard condition encountered on the ground locations.

2) A walker in rainwater by the submerged electric facility can also be involved in an electric field in the water. This results from electric current flowing in the water between two parts of unequal potential. This electric field is expressed as volts per centimeter of distance in this study.

3) The walker located in rainwater where it has assumed potential with respect to above-water conductive objects, is located where he can contact them.

To estimate electrical hazards of the human body in the water, electric potential as a function of distance was measured by simulating leakage situation of submerged electric facility using a reduced scale of 1:10 in the laboratory. The characteristic curve of the body current[3] was determined by considering the shock duration and minimum value of the body resistance, which was used to calculate separation to guarantee the safety of the human body.



(a) line source (b) line source in box

Fig. 1. Experimental setup for the measurement of electric potential in fresh water.

2. EXPERIMENTAL SETUP

Fig. 1 represents a situation of electric shock in fresh water due to the leakage of submerged electric facility. It was conducted by using a reduced scale model at a scale of 1:10 in the laboratory. To assess the hazard of the human body, experiments were conducted in a water tank. The size of the water tank was a 100x100x75 cm rectangular type and the thickness of tank was 6 mm steel. The human body was modeled at a scale of 1:10 copper rod with length, 17 cm and diameter 1.6 or 3.5 cm. This was based in the assumption that the height 170 cm and the weight 75 kg of the human body was modeled by about 35 cm diameter-cylinder shape with the same surface area[4]. Thus in a case that the diameter of copper rod was 1.6 cm, a pathway of current was one foot and in this case 3.5 cm, and the pathway of current was the body. The submerged depth was tested at 5 cm, 8.5 cm for these two cases. This idea was obtained from the theory[5,6] "that the ground resistance of the foot is taken as equivalent to the ground resistance of a circular conducting disc having a radius of 8 cm and placed horizontally on the surface of the ground". The following two different types of voltage source: (a) Line source and (b) Line source in box, were experimented. The source voltage was applied from 100 V to 220 V at intervals of 20 V. The electric potential was measured between the copper rod and the water tank at 3, 5, 10, 20, 30, 40, 50 cm from the voltage source.

3. RESULTS

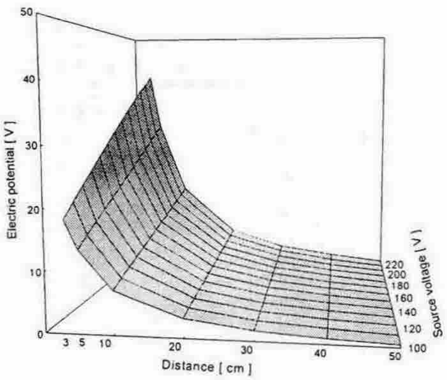


Fig. 2. Electric potential with a line source I in case of submerged depth =5 [cm] and rod diameter=1.6 [cm].

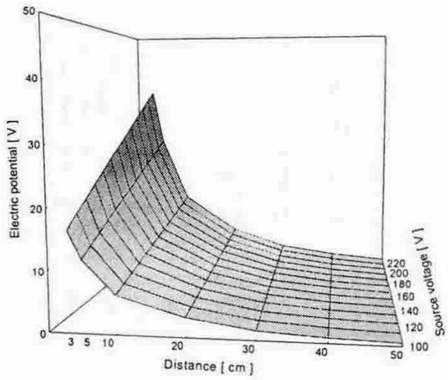


Fig. 3. Electric potential with a line source I-1 in case of submerged depth =8.5 [cm] and rod diameter =3.5 [cm].

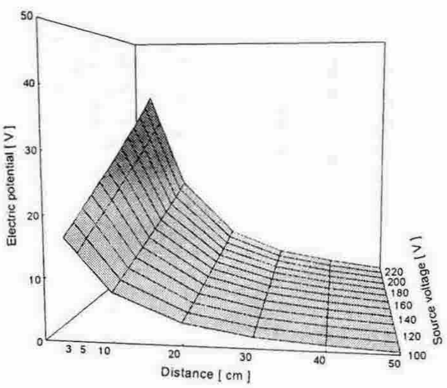


Fig. 4. Electric potential with a line source II in box in case of submerged depth=5 [cm] and rod diameter=1.6 [cm]

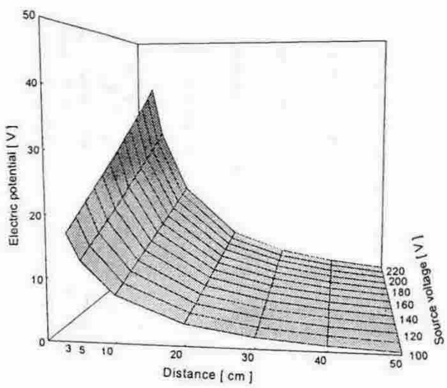


Fig. 5. Electric potential with a line source II-1 in box in case of submerged depth=8.5 [cm] and rod diameter=3.5 [cm].

In cases that the types of leakage point, distance from leakage point to the copper rod, diameter and depth of the copper rod and magnitude of the applied voltage were varied, the results of electric potential distribution are shown in Fig. 2 to 5. Fig. 2 to 3, show electric potential in a case where the type of the leakage point was line. When the type of the leakage point was line in box, electric potential is shown in Fig. 3 to 4. In both cases, there was a rise of electric potential (about 40 V) as a copper rod approached the leakage source from 50 cm to 3 cm. As the kind of leakage source, the submerged depth and the diameter of a copper rod were varied, there was little difference for electric potential.

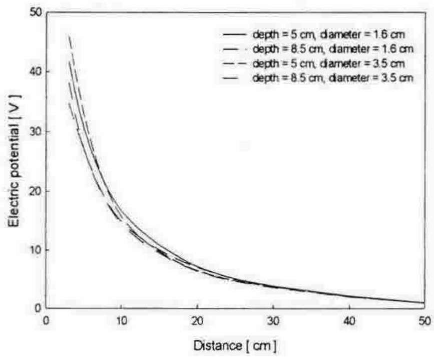


Fig. 6. Electric potential vs. distance from a line source at 220 [V].

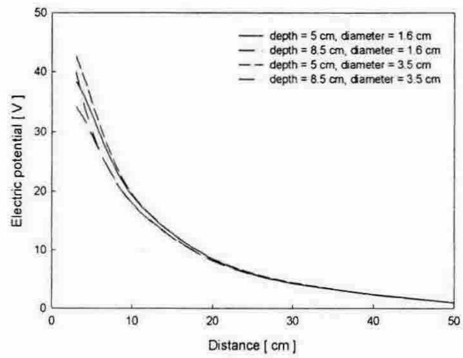


Fig. 7. Electric potential vs. distance from a line source in box at 220 [V].

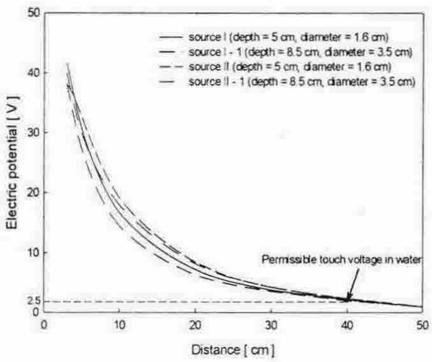


Fig. 8. Electric potential vs. distance at 220 [V].

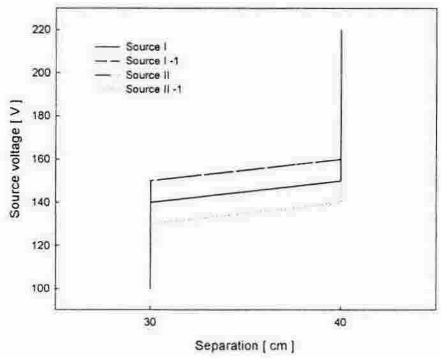


Fig. 9. Source voltage vs. separation in case of permissible touch voltage, 2.5 [V].

Fig. 6 to 7 represent the relation between electric potential and the distance from leakage source to copper rod at 220 V. Fig. 8 shows that the value of separation is about 40 cm in a case where permissible touch voltage of the human body was 2.5 V. This value is permissible touch voltage in a case where most of the human body was submerged in water. The relationship between the variation of leakage voltage and the separation, in a case where permissible voltage was 2.5 V, is shown in Fig. 9. As the voltage of leakage point varied from 100 to 220 V, the separation by leakage source was 30 to 40 cm.

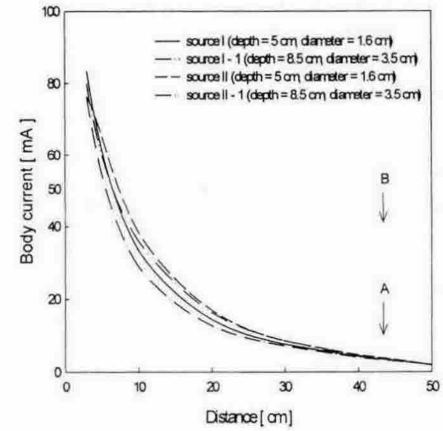


Fig. 10. Body current vs. distance at 220 [V].

Fig. 10 shows body current that varied with the distance from the leakage source. Dotted line A represents a muscular contraction or a difficulty in breathing that can be occur. Dotted line B means possibility of a ventricular fibrillation. Thus, the separation to prevent a muscular contraction and a ventricular fibrillation are 10 and 20 cm respectively.

4. CONCLUSIONS

The quantitative hazard of the human body due to electric shock in water was assessed with a small scale in the laboratory. And the conclusions of this study were as follows:

1) In cases where the kind of leakage source, the submerged depth and the diameter of a copper rod are varied, there is little difference for electric potential.

2) In both cases where leakage sources are line and line in box, there was a rise in electric potential, about 40 V as a copper rod approached the leakage source from 50 cm to 3 cm.

3) On the assumption that permissible touch voltage is 2.5 V (in a case where most of the human body is in water), the minimum value of separation was estimated, at 40 cm.

4) In a case where body resistance was 500 Ω and the shock duration was 1 sec. the limit value of the body current was 20 mA and 50 mA, and the separation was presumed at 20 cm and 10 cm respectively.

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