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## OCCUPATIONAL INJURIES CAUSED BY ELECTRICITY\*

The present investigation has shown that accidents due to electric current cause a very great number of deaths and give rise to a high percentage of invalidity. A long period of hospitalization has as a rule ensued. Both from the social standpoint and from the point of view of occupational hygiene it is a matter of pressing urgency to reduce these figures if possible. The investigation carried out points to certain possibilities in this connection. The large number of traumatic injuries in connection with accidents due to electricity would probably be able to be considerably reduced by more effective precautionary measures of various kinds. As regards the burns, the possibilities of preventive measures seem to be fewer. The kidney injuries caused by electric current are, it is true, few in number, but they are as a rule dangerous to life. It should, however, be possible to reduce the risks of death in these cases by applying an effective alkali therapy.

The use of electricity has shown an enormous increase since the beginning of this century, and the introduction of electric energy has meant a revolution of world industry. During the period 1907—1930, for example, the use of electric energy in the industries of Great Britain increased by nearly 900%, while the use of mechanical power decreased by more than 13%. In Sweden the use of electric energy is so widespread that only one country, namely, Norway, can show a higher kilowatt consumption per head of the population. The consumption reckoned in this way in Sweden amounted for the year 1936 to 1070 kilowatts and for Norway to 2650 kilowatts. By way of comparison, it may be mentioned that the corresponding figure for Yugoslavia for that year (1936) was 9 kilowatts.

During the last years, very large electrical power plants have been built in Yugoslavia and now the consumption will rise to about 300 Kwh per capita.

The frequency of accidents due to electricity will of course bear a certain relation to the consumption of electrical energy. As regards Sweden, such accidents constitute a great and serious problem. I shall illustrate this in the following with the results of some investigations that have been carried out in our country.

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During the period 1930—1944, 2965 accidents due to electricity occurred in Sweden. Distribution of accidents among different places of work is shown in table 1.

TABLE I

Incidence of accidents at different places of work Razdioba nesreća prema mjestu rada	
Industries — Industrija	1097
Power stations and transformer stations — Električne centrale i transformatorske stanice	619
Overhead cables — Kablovi nad zemljom	483
Underground cable system — Kablovi pod zemljom	32
Dwellings — Nastambe	364
Tramways — Tramvaji	130
Railways — Željeznice (električne)	240

Of the accidents occurring, 448 proved fatal, while 157 led to invalidity in some form or other.

It has seemed to me to be of very particular interest to make a detailed analysis of these accidents in respect of their causes. To what extent have these accidents been due to the victims themselves, and to what extent can other factors be made responsible for the accident?

The result of such an analysis may be seen from table 2.

It is remarkable to find that the victim himself is to be regarded as responsible for the accident in no fewer than 55.4% of cases, and that in this connection carelessness is represented by the figure 45%. Also as regards the fatal cases, the percentages of the corresponding factors are of the same order of magnitude. Under the heading »Pure accident«, on the other hand, one finds an almost negligible figure, both for the total number of cases and for the fatal cases. This shows what a dominating rôle the »human factor« plays in the origin of accidents due to electricity.

From the medical point of view it has been of interest to make a more detailed study of the nature of the injuries due to electricity and the degree of their severity. I have done this on material taken from the period 1924—1933. During these years there were 1479 accidents due to electricity in Sweden, of which number 285 were fatal. The distribution of the accidents and deaths per year may be seen from the diagram in table 3.

More circumstantial reports and more detailed information concerning the fatal cases and the more serious accidents have been available only to a certain extent, and the figures I shall adduce in

TABLE 2

Main responsibility Glavna odgovornost	Total No. of cases Ukupni broj slučajeva		Deaths Smrti	
	No.	%	No.	%
<b>1. On part of authorities Na vlastima</b>	1012	34.1	123	27.4
Dangerous lay-out Opasna instalacija	556	19.1	102	19.4
Temporary defect Povremeni defekt	442	14.9	21	4.7
Other cases — Ostali uzroci	4	0.1	—	—
<b>2. On part of injured person Na unesrećenoj osobi</b>	1643	55.4	247	55.4
Temporary forgetfulness Povremena zaboravljivost	178	6.0	55	12.3
Misunderstanding Nesporazum	12	0.4	2	0.5
Ignorance — Neznanje	58	2.0	20	4.5
Carelessness — Nemarnost	1336	45.0	150	33.6
Mischievousness — Zloba	55	1.9	20	4.5
Other cases — Ostali uzroci	4	0.1	—	—
<b>3. Caused by another person Uzrokovana od druge osobe</b>	265	9.0	73	16.0
<b>4. Pure accident — Očite nesreće</b>	44	1.5	4	0.9
<b>5. Other cases — Ostali slučajevi</b>	1	—	1	0.2
Total Ukupno 1—5	2965	100.0	448	100.0

the following do not, therefore, cover all the accidents occurring during the period 1924—1933.

As concerns the fatal cases. I have calculated the time that has elapsed from the occasion of the accident until death supervened. Traumatic injuries have been excluded from this material. (Table 4).

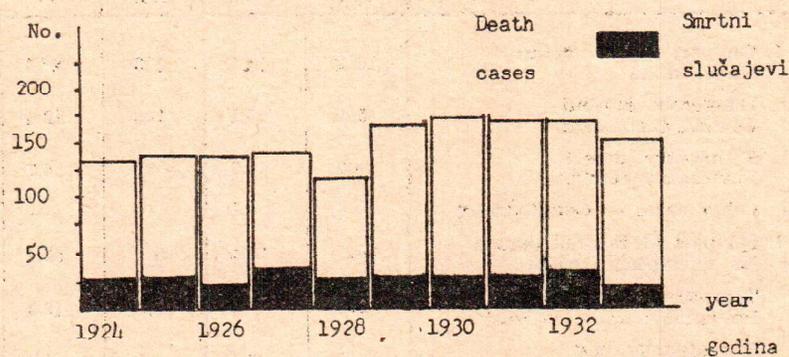
From this table it emerges that the relative number of cases of instantaneous death is greater in connection with lower tension than with higher tension. This at first sight curious circumstance seems to be explicable in the light of the effect upon the heart of different strengths of current.

According to a number of writers (*Koeppen, Prevost and Battelli, Schlonka and Schrader* and others), the strength of current that is most dangerous for the heart lies between approximately

TABLE 3

DISTRIBUTION OF ACCIDENTS OVER THE PERIOD 1924 - 1933.

KRETANJE NESREĆA U VREMENU OD 1924. - 1933.



0.08—4 Amperes. A current of this strength frequently causes ventricular flimmer. With tensions of between 100—500 volts and a calculated electrical resistance in the body of 1000 ohms, the strength of current will lie precisely within this range so dangerous to the

TABLE 4

Period of survival Vrijeme, koje je pro- teklo od ozljede do smrti	Tension in Volts Napon u Voltima				Total Ukupno
	—220	—500	—1000	—10000	
Death instantaneous Trenutačna smrt	18	88	76	40	222
Death within 7 days Smrt u roku od 7 dana	0	1	7	7	15
Death within 14 days Smrt u roku od 14 dana	0	0	2	2	4
Death after 14 days Smrt iza 14 dana	0	1	2	1	4

heart, the so-called Koeppen's third current-intensity range. At higher tensions (10000—100000 volts), on the other hand, and with normal electrical resistance in the body, the ampere-index will considerably exceed the dangerous current-intensity range. But

through the burns inflicted the electrical resistance in the body may be so considerably increased that the strength of current will be reduced to values dangerous to the heart.

As regards the nature of the injuries inflicted in accidents due to electricity which have led to hospitalization, these may be referred to two large groups, namely, burns and traumatic injuries. In the hospital material the burns constituted the majority of the injuries, or 75%.

The frequency of burns in the different tension ranges may be seen from table 5, where the number of burns among the total number of injuries sustained within the respective tension ranges has been given.

TABLE 5  
Distribution of the Burns  
Razdioba opeklina

Tension in Volts Napon u Voltima	%
— 220	32
— 500	59
— 1000	88
— 10000	98

From table 5 it emerges that the number of burns rises with increasing tension. As the electric burn arises as a rule through the development of heat in the tissues on the conversion to heat of the electric energy according to Joule's law, it is reasonable to find a distribution of this kind. Only in a smaller number of cases was the burn caused by an electric arc arising.

It appeared to be of a certain interest to investigate the localization of the burns. This has been possible in 98 cases, which are accounted for in table 6.

As was to be expected, one finds the burns all localized to the upper extremities (73%). It is more surprising to find that such a relatively large number of burns (18%) are facial injuries.

The burns have as a rule been severe, and have been mainly listed as burns of the 2nd and 3rd degree. This is also reflected in the average sick period, calculated for the 77 cases in which only burns were sustained. The period in question has amounted to 160 days.

TABLE 6  
**Localization of the Burns**  
**Lokalizacija opekline**

Localization Lokalizacija	No.	%
Skull — lubanja	8	8
Face — lice	18	18
Upper extremities — gornji ekstremiteti	72	73
Lower extremities — donji ekstremiteti	30	31
Trunk — trup	24	24

The traumatic injuries have as a rule been sustained after a fall from pylons in connection with contact with current. In the hospital material investigated there were 69 cases (77%) with such injuries.

The number of traumatic injuries among the total number of injuries sustained may be seen from table 7.

TABLE 7  
**Distribution of traumatic injuries**  
**Razdioba traumatskih ozljeda**

Tension in Volts Napon u Voltima	%
— 220	68
— 500	54
— 1000	43
— 10000	29

A relatively larger number of cases of traumatic injuries is found in connection with lower tension. It does not seem possible to discover the reason for this at the present stage of the investigation.

The traumatic injuries have as a rule been of a very serious nature, with bad fractures often localized to the spine and the pelvis. Even where the fall was from a relatively low height, the injuries have been surprisingly grave, which is probably connected

with the fact that these individuals generally fall down in an unconscious or comatose state, and are thus not able to break their fall. The average sick period for the traumatic injuries alone was 209 days.

Of recent years the kidney injuries connected with accidents due to electricity have attracted particular attention. Fischer and his co-workers (1947) have shown that high-tension accidents, which are connected with more or less extensive injuries to the musculature, may give rise to kidney injuries which may endanger life. These are considered to arise through the separation of myoglobin from the muscle-tissue and injury to the tubular apparatus on its excretion with the urine, with kidney insufficiency as a consequence, which has in many cases led to the death of the victim. As one has the possibility of preventing this kidney insufficiency by applying an early and energetic alkali therapy, it is of the greatest importance that these cases should not be overlooked.

The author has tried to obtain information from the whole of his material (477 cases) as to whether there has been kidney injury or not in connection with accidents due to electricity. This question has been answered in 123 cases, but kidney injury was considered to have occurred in only 8 cases. Whether in these cases the kidney injury was due to myoglobin or not cannot be decided, as no myoglobin analyses were carried out. One must not, however, consider this etiology improbable, as all of these cases had had contact with high-tension electric current. Of the cases listed as kidney injuries, 4 died. Since, as has been mentioned above, an effective therapy for these cases is considered possible, it is evident that an examination of the urine for the occurrence of myoglobin is necessary in connection with high-tension accidents.

Invalidity in the technical sense used by insurance companies has occurred in 63 cases, amounting to one fourth of all the surviving hospital cases observed by the author. The degree of invalidity in these cases may be seen from table 8.

TABLE 8

Degree of invalidity Stupanj invaliditeta	No. of cases Broj slučajeva
— 25%	20
— 49%	20
— 66%	8
66%	15

Of the total number of cases, the traumatic injury alone caused the invalidity in 19 cases, while the invalidity was caused by the burn alone in 31 cases. In 13 cases it is not possible to decide definitely whether the burn or the traumatic injury was the cause of invalidity, as injuries of both kinds has occurred simultaneously.

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#### SADRŽAJ

Istraživanja su pokazala, da se ozljede električnom strujom vrlo često svršavaju smrtno i uzrokuju veliki procenat invaliditeta. Unesrećeni električnom strujom liječe se vrlo često dugo vrijeme u bolnici. Iz socijalnih razloga, a i sa stajališta industrijske higijene treba izvršiti sve mjere, da se broj ozljeda električnom strujom smanji. Utvrđeno je, da je to donekle moguće. Velik broj traumatskih ozljeda, do kojih dolazi u vezi s nesrećama od električne struje, mogao bi se znatno smanjiti pomoću raznovrsnih preventivnih mjera. Kod opekline, je to već mnogo teže.

Ozljede bubrega uzrokovane električnom strujom su vrlo rijetke, no takve ozljede su redovno opasne po život. Bilo bi moguće, da se u tim slučajevima smrtnost smanji, ako se na vrijeme primijeni terapija s alkalijama.

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