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INTRODUCTION

This paper presents the final results of the effects upon the health of linemen engaged in the maintenance of energized electrical transmission over a period of nine years. An initial report^{1,2} was presented in 1966 at the IEEE Summer Meeting in New Orleans, and the study has been continued to 1972. The evaluation was begun in December 1962 with ten linemen, four from the Ohio Power Company and six from the Appalachian Power Company (American Electric Power System).

In order to assure reliable and continuing electric service most of the present day low voltage lines and all of the HV and EHV lines are kept energized during maintenance work. The linemen have the duty of working on these lines while energized. They are exposed to electrical fields of various intensities while carrying out their duties. They are not substation operators. The American Electric Power Company and many other U. S. companies operate their switching stations by electric relays controlled from distant load centers.

Various maintenance techniques have been developed that permit this live-line maintenance to be done safely and efficiently. Two distinct techniques are employed today, the hot stick method and the bare hand method. A lineman using the hot stick method is separated from the high field surrounding the energized line conductor by the effective length of the hot stick (10 feet for 345 kV) and is exposed only to a field strength of around 2 kV per inch (70 kV/M) when working 345 kV. The small 60 Hz AC electrical currents which the electric field produces enters the entire surface of his body and flows to ground through his feet which are usually in contact with ground.

In case of bare hand work, the lineman is adjacent to the energized conductor, in fact is bonded to it, and is exposed to a strong electric field (up to 12 kV/inch (470 kV/M)). He is protected from the electric field either by wearing conductive clothing and gloves or by Faraday screens. If his head is not screened from the field, a current of a few microamperes enters his face and passes out of the back of his head.

Because of undocumented statements of ill effects to men working in the electric field, a medical study was undertaken under the direction of members of the Staff of The Johns Hopkins Hospital to determine the possibility of any effects. In 1966 and 1967, a total of five IEEE transaction papers² were published reporting on the results of the study to 1965. That paper presenting the medical evaluation of the linemen included data on the field intensity and body currents encountered

by men working in the 345 kV electric field with no shielding and with partial shielding.

The examinations were conducted in the Private-Out-Patient Department of the Johns Hopkins Hospital between December 17, 1962 and June 23, 1972. During this period of nine years, the men were examined completely seven times. The men selected were all linemen who were in excellent health. The age range at the beginning of the examinations was 30 to 47, which places the men now in the range from 39 to 56. Table I gives some general information concerning the linemen. The men from the Ohio Power Company worked bare handed on the 765 kV lines and, also, performed so-called hot stick maintenance work. The men from the Appalachian Power Company worked very little bare handed, but accumulated a large number of hours with the hot stick technique. The hands of linemen working bare handed on high voltage lines were protected from the electric field by conductive gloves as they are subjected to an intense electric field. The men normally worked a forty hour week on maintenance service. Eight of the group are now in supervisory positions. However, they are still exposed to high voltage gradient as they climb the towers to better supervise the repairs. In our earlier publications^{1,2}, after three and one-half years, we had reported on eleven men. The eleventh subject (#3 in the earlier publication) entered the study late (1965) and gave up his employment after 1967, so he is not included in this survey. His withdrawal from the study does not constitute any major loss, since his accumulated data covered such a brief period. No physical defects were found in him.

NATURE OF THE STUDY

The examinations consisted of a complete medical history and physical examination, and a repeat interval history and physical examination on each of the linemen performed at intervals over the nine years. There were a total of seven examinations for each of the linemen over the years. The histories and physical examinations were performed by the same physician (M. L. Singewald, M. D.) an internist, who also supervised the complete medical and laboratory survey of each of the men. The medical survey consisted of consultations with an ophthalmologist, an otolaryngologist, a urologist, and a neuro-psychiatrist (O. R. Langworthy, M.D.) at each of these examinations.

The laboratory survey consisted of a complete hematological study and blood chemical studies, which included serum urea nitrogen, blood sugar, and serum cholesterol, uric acid, urine analysis and stool examination. Thyroid function was measured by the protein bound iodine test up to 1968 and the T-4 test thereafter. Kidney function was evaluated by Phenolsulfonphthalein test and urea clearance test up to 1968, and the creatinine clearance test thereafter. The function of the liver was evaluated by the bromsulfalein test up to 1968 and also the Cephalin Flocculation and Thymol Turbidity tests. After 1968, chemical screening battery was used, which includes Bilirubin and the series of enzymes and alkaline phosphatase. The test in addition includes calcium phosphate, glucose, urea nitrogen, uric acid, cholesterol, total protein, and albumin. Twelve lead electrocardiograms were obtained at

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each of the examinations. Electroencephalograms were recorded, using 18-21 electrodes with both bipolar and common reference techniques. Awake recordings were augmented with sleep tracings when possible. Hearing was tested by the audiometer technique, using the air conduction pure tone test. X-rays of the chest and hands were obtained at each of the examinations. The urologist obtained a sperm count at each examination. Each of the seven complete medical examinations at the Hopkins Hospital required three and one half days.

RESULTS OF THE STUDY

There were no significant changes of any kind found in the general physical examinations. The men remained essentially healthy. They all gained weight over the nine years, the median weight gain was 14.8 pounds. Subject #7 developed a "coin lesion" in the lung between the examination of 1970 and 1972. This lesion was biopsied and proved to be a benign inflammatory granuloma. There was no malignancy.

Specifically, in this nine year follow-up there was no change in the skin or hair. The hands remained normal by examination and by X-rays. There was no change in the cardiovascular function or respiratory system. Eye examinations were normal. No evidence was unearthed of any malignancy of any kind that could be detected by the methods of the study. There were no significant abnormalities in any of the laboratory studies. The consultants found no disease states which could be in any way related to the exposure to HV lines. Hearing, as measured by the audiometer test, showed no change. Electroencephalograms remained normal. There were no significant visual problems. The psychiatrist could not detect any significant change in emotional status in any of the men that could be related to this study.

Dr. Langworthy, the psychiatrist, saw each of the men at each of their seven examinations and, thus, had the opportunity of rapport becoming quite familiar with them, and learned much of their emotional background and life adjustment. He rated them from 2+ to 4+ as to their emotional grading with 4+ being the highest. Four of them rated 2+, four rated 3+, and two rated 4+. It is of interest that the ratings of these men using another method, by the three authors nine years before, correlates very closely to the present rating. These observations are clinically relevant, and are directly opposite to the comments of Asanova and Rakov³ of

Russia. These authors mention "disorders of the functional state of the nervous and cardiovascular system." Our ten subjects did not complain of anything in this realm over the nine years of observation. Comparison of two diverse populations with entirely different cultures, working conditions, and environment, should be viewed with great caution. However, we have mentioned the Russian paper to document the fact that we are aware of it.

We learned that sperm counts are quite variable, depending on time of collection in relation to sexual habits. Sperm counts in a number of the men were abnormal one day, and above normal two days later. With such a variability, it would be hazardous to draw any conclusions, particularly from this small sample. In several of the subjects, the counts were up one year and down the next, but it is of real interest that in 1970 (at the seven year point of the study), every man had a normal sperm count. In 1972, there were three abnormal counts, one of these occurring in a man who had been told some years before the study began (13 years), that he had low counts and that he was clinically sterile. In spite of this, he had a normal count in 1970. We must conclude that sperm counts were not influenced by the exposure to electrical fields. The Urologist, was unable to find any evidence of genitourinary disease in these ten men.

CONCLUSIONS

Over a nine year period of observation and study, ten linemen have been carefully examined and followed by a team of physicians. It can be reported that the health of these ten men has not been changed in any way by their exposure to HV lines, within the limits of these studies on this sample.

To put our medical study in perspective in regard to the overall problems of intense AC electric fields and their effects on human beings we have made the following conclusions:

1. No measureable X-ray radiation was found.
2. Electric currents are induced in a conductive body when in an AC electric field.
3. Currents that may flow in a lineman's body when working bare handed may reach high values if the lineman is not shielded. These currents are essentially sinusoidal.
4. Protection from electric fields may be provided by suitable Faraday screens or by conductive clothing. Insulators offer no protection.

TABLE I

| SUBJECT NUMBER | AGE 1972 | AGE 1963 | YEARS WORKED | AGE STARTED WORK | AGE MARRIED | NUMBER OF CHILDREN |
|---------------------------|----------|----------|--------------|------------------|-------------|--------------------|
| OHIO POWER COMPANY | | | | | | |
| 1 | 40 | 31 | 22 | | | |
| 2 | 45 | 36 | 26 | 18 | 26 | 1 |
| 4 | 41 | 32 | 23 | 19 | 21 | 3 |
| 5 | 44 | 35 | 25 | 18 | 21 | 7 |
| | | | | 19 | 22 | 4 |
| APPALACHIAN POWER COMPANY | | | | | | |
| 6 | 47 | 38 | 23.5 | 23.5 | 25 | 0 |
| 7 | 47 | 38 | 18 | 28 | 18 | 2 |
| 8 | 39 | 30 | 16 | 23 | 24 | 3 |
| 9 | 40 | 31 | 12 | 29 | 17 | 4* |
| 10 | 56 | 47 | 35 | 21 | 31,46 | 0 |
| 11 | 43 | 34 | 21.5 | 22.5 | 26 | 1 |

* one child born during study

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ABSTRACT

The medical evaluation by members of the Johns Hopkins Hospital Staff of possible effects of 60 Hz AC fields on linemen involved in maintenance of energized HV and EHV lines using the hot stick and bare hand techniques was reported in 1966 in References 1 and 2. This paper supplements that information with the data from the continuing nine year medical study, including extensive periodic physical and psychological examinations, of the eleven men involved in the original program. The conclusion of the initial report that the health of the men was not affected is confirmed.

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