

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILES 86/2
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site of The Falkirk Mining Company, was struck by the United Mine Workers of America from January 12 through June 7, 1975. However, we did resume operations at the mine during the period with management personnel and later with permanent replacement employees.

During the strike, the United Mine Workers insisted on a number of demands, the most objectionable of which was a so-called "accretion" or "coal lands" clause which has heretofore been agreed to by every coal company in the United States under contract with the UMWA. This clause stated that any future operations of our Company or its subsidiaries in North Dakota, including The Falkirk Mining Company, must automatically be under the jurisdiction of the United Mine Workers when the first man is hired. This provision clearly would preclude any future employee's right to determine his own bargaining agent or union representation, if, in fact, he would want any.

We are pleased to inform you that the terms and conditions of the agreement eventually negotiated covers only operations of our Indian Head Mine, and that there is no accretion or coal lands clause in the contract which gives the United Mine Workers any jurisdiction at any other operation of North American or its subsidiaries in North Dakota, including The Falkirk Mining Company.

As you know, at this moment some 40,000 UMWA workers are participating in illegal, unauthorized strikes in the Appalachian Region. As I mentioned previously, our Company lost one million tons of production

last year due to these illegal work stoppages, and has lost nearly this amount of production so far this year. Should the United Mine Workers of America gain the strength in North Dakota that they currently enjoy in the Eastern coal fields, the continuity of our operations, and hence, of your coal supply, cannot be assured. It is for this reason that we at The Falkirk Mining Company are deeply committed to the preservation of non-union status.

The new managerial approach which we are developing for Falkirk is not merely an attempt to keep the union out. It is a positive effort of restructuring our employees' relations to increase productivity and motivation. Lines of authority will still exist between managers and miners, but we are attempting to develop a mutual trust with our employees which will break down the divisions of labor which have evolved with unionism. By adopting these more sophisticated industrial relations concepts and techniques, and through salary, benefit, and job security programs, we hope to avoid the costly wildcat strikes, rigid work rules, grievance procedures, general worker dissatisfaction, and decreased productivity, which have stemmed from the traditional adversary relationship of management and union.

In addition to the above typical business problems, we have other problems unique to our industry, which are impeding Western coal development. These center on environmental and socio-economic impacts, public

opinion, and government action.

The development of Western coal reserves must not -- and need not -- result in any environmental deterioration. The environmental ethic must be recognized as a fact of life by all coal developers, particularly the concern for mined land reclamation.

The following series of slides depicts the steps in the reclamation process at our Indian Head Mine near Beulah, North Dakota. These same techniques will also be employed in the reclamation work at The Falkirk Mining Company.

Topsoil Removal

Grading

Topsoil Replacement

Tilling and Seeding

Slides of Completed Work

Although we can -- and are -- restoring mined land to its original or better topography, reclamation must be measured by the ultimate productivity of the land. It is reasonable to believe, however, that if all topsoil and subsoil, which contain the nutrients essential to native plant growth, are restored, then reclaimed land should be as productive as it was originally. Two of the primary questions are: (1) "How much topsoil and subsoil should be restored to achieve this?", and (2) "What methods should be employed to prevent contamination of this surface material?"

To find the answers, we are cooperating with universities and government agencies in conducting reclamation research. North American is currently working with the various departments of the North Dakota State University, Montana State University, (through a United States Environmental Protection Agency grant), the Agricultural Research Service of the U. S. Department of Agriculture, the Soil Conservation Service, the North Dakota Geological Survey, and the North Dakota Mined Land Planning Group. Aspects of reclamation under investigation in these instances include natural succession of reclaimed lands, root zone hydrology, surface water run-off, surface manipulation, aquifer analyses, segregation of topsoil and subsoil, reforestation, nurse crops, refertilization, soil amendments, seed varieties, and vegetative covers.

By 1978, when large-scale mining begins we should have the answers
and the necessary technology to restore the land to its original productivity.

In response to public demands, reclamation legislation at both the State and Federal levels has rapidly evolved which may, in fact, impede effective mined land reclamation. In many instances, these regulations are not based on current scientific evidence, and they also do not permit the flexibility required from area to area to achieve satisfactory reclamation. This "cart before the horse" philosophy of passing laws before the technology is available must be changed if we are to solve mined land reclamation problems and if the surface coal mining industry is to grow in the West.

Other problems which must be solved if Western coal development is to accelerate are those involving the social and economic impacts in the affected areas. There is no question that funds must be generated from the coal development projects to cover these impacts and the need for services and facilities in the impacted communities. However, many in government use this concern for the socio-economic impacts to promote legislation which, in fact, may eliminate coal development altogether.

But state and local problems aren't coal development's only stumbling blocks. Federally-controlled lands containing huge coal reserves checker-board many privately-held leased lands. Yet the Federal government has no firm leasing policy and has had a moratorium on Federal coal leasing since 1971. Fortunately, however, there are less than 1,000 acres of Federally-controlled lands in the reserves of The Falkirk Mining Company.

The coal industry, and, indeed, those genuinely concerned about the energy problems confronting this nation, have had much difficulty convincing the Congress of the seriousness of the situation. It is imperative that cooperation, rather than confrontation, mark the future relationship between our industry and government.

Assuming the myriad of environmental, public opinion, and governmental problems can be solved, the development of these large electric power generation and gasification projects proposed for the West, and particularly the Northern Great Plains, may actually be undertaken.

At this time, I would like to outline the steps in the actual development and construction of The Falkirk Mining Company project.

The first step was an extensive exploration program by The North American Coal Corporation of the potential coal reserves within a five-mile radius of the city of Underwood, North Dakota. An initial drilling program was carried out to determine the presence and quality of the coal deposits and the type and depth of overburden in the area.

As was mentioned earlier, the coal reserves of North Dakota are of a very low grade, known as lignite. While lignite contains only about 60 per cent of the calorific value in BTU's per pound of typical Eastern bituminous coal, it lends itself to very economical mining. This is due to the fact that lignite is typically found in comparatively thick seams in relatively close proximity to the surface, and is overlain primarily by sandy shales and clays which are easy to mine.

Our initial exploration and drilling program revealed that these reserves in the vicinity of Underwood, North Dakota had great potential for development. We determined that over 300 million tons of economically-mineable coal exists in a block within a five mile radius of the city of Underwood. Also, this lignite was found to contain approximately 6500 BTU's per pound, 39 per cent moisture, 7 per cent ash, only 0.6 per cent sulphur, and a very low sodium oxide content in the ash. This analysis indicates that these reserves will be a very satisfactory boiler fuel.

This slide shows the reserves which we defined, and which were eventually to become the reserves of The Falkirk Mining Company and the fuel supply for the Coal Creek Station. This view shows the outcrop and extent of these reserves with reference to the City of Underwood and to Falkirk's coal delivery point.

Based on our newly-acquired information regarding the quantity, quality, and mineability of the reserves in the vicinity of Underwood, an extensive surface and coal lease acquisition program was undertaken. Also, an initial mining plan was developed and capital and mining cost projections were prepared.

At about the same time North American was conducting its exploration and surface and coal land acquisition programs, the Cooperative and United Power Associations were considering the siting of a new mine-mouth generating facility in North Dakota. As a result, North American's entire package was presented to the Cooperative and United Power Associations.

Based on the attractive mining costs achievable from these reserves, the proximity of these reserves to an excellent water supply, and the location of these reserves to our customers' markets, the Cooperative and United Power Associations indicated a definite interest in these reserves as a potential fuel supply.

At this point, a wholly-owned subsidiary of North American, The Falkirk Mining Company, was incorporated to negotiate a Coal Sales Agree-

ment with CPA-UPA. The Agreement eventually negotiated is extremely complicated and includes provisions by which The Falkirk Mining Company is to be financed.

Historically, the coal industry has experienced low profit margins. Even though North American has existed for more than 60 years, we have never been able to establish the net worth required to finance operations such as The Falkirk Mining Company, which will cost about \$128 million to build, based on current price levels. As a result, we have necessarily resorted to methods of financing not guaranteed or secured by North American. Typically, North American will assign the coal reserve to a subsidiary company, such as The Falkirk Mining Company, and this subsidiary will execute a cost-plus, long-term coal sales agreement with the utility customer. The Falkirk Mining Company has the responsibility for constructing the operation and for mining the required coal, while CPA-UPA must provide the required financing either directly or via loan guarantees.

In order to assure efficient mining operations and the lowest possible coal costs to CPA-UPA, incentive provisions are included in our extremely complex contract. Depending on how The Falkirk Mining Company performs compared to a standard cost of production negotiated at the end of the mine development period, Falkirk can make more or less than the standard profit set forth in the agreement. Through these financing arrangements, a low-cost feedstock or boiler fuel is provided the utility while our company is able to expand.

I am convinced that through this contractual arrangement, and in view of the comparatively favorable mining conditions to be encountered at the Falkirk site, the lignite delivered to the mine-mouth Coal Creek Station will be one of the lowest cost coal boiler fuels available in the United States.

Following the consummation of the Coal Sales Agreement and the financing arrangements, the actual construction of The Falkirk Mining Company has been undertaken. Additional exploration drilling is now being assembled to further define and analyze the coal reserves for actual mining, to identify and evaluate associated aquifers, and to determine the physio-chemical properties of sub-surface materials lying above the coal seam. This information is being used to develop final mining plans and methods, and to determine mining equipment specifications.

The mining system, methods, and equipment to be employed are similar to those currently in use at our Indian Head Mine, although the Falkirk operation will be five times the size of the Indian Head Mine and will be far more complicated, which I will explain later.

The following series of slides shows the mining operations at our Indian Head Mine:

1. As previously mentioned, the first step in the coal mining operation is carried out with reclamation in mind. Here a tractor-scraper removes the topsoil and suitable sub-soil.

The soil is stockpiled for replacement later during the reclamation process.

2. In the next step, a large shovel, called a dragline, removes layers of soft sandy-shale overburden material until it reaches the coal seam, as much as 135 feet below the surface.

I previously mentioned that the operations at The Falkirk Mining Company will be somewhat more complicated, in addition to being five times larger than those at our Indian Head Mine. These complications are, in part, the result of the fact that much of the overburden at the site of The Falkirk Mining Company consists of glacial alluvium or till, i.e., a very sandy unconsolidated material strewn with boulders. This material is very unstable, particularly when wet, and therefore sloughing of pit high walls will undoubtedly be a problem, and, more importantly, very flat angles of repose will result for the high wall and spoil piles. These flat angles of repose have necessitated the use of extremely large draglines for the overburden removal operation.

The two primary overburden draglines on order for The Falkirk Mining Company will be the largest machines of their class ever built and will be similar, but larger, than those shown

in this series of slides. These two Marion Power Shovel Company Model 8750-30 machines will have 105 cubic yard buckets capable of lifting approximately 152 tons per bite, and will be powered by electric motors totalling 13,000 horsepower. Due to the flat angles of repose to be encountered, as previously described, these machines will have the longest booms ever ordered for a dragline. The booms will be 350 feet long, giving each machine a 328.5 foot operating radius. Imagine, one of these machines could be positioned between two football fields placed end to end, and it would be able to lift 152 tons from well in the end zone of one football field and place it deep in the end zone of the second football field over 218 yards away.

These machines must be large because, based on the thickness and depth of the coal to be mined, these two machines must remove nearly 50 million cubic yards, or 75 million tons of overburden annually to produce the six million ton annual coal requirement.

3. Another complication to be encountered in the mining sequence at the Falkirk operation is the fact that the reserves occur in two distinct seams, as shown in this slide of a typical pit cross section. The top seam will normally be about 8 feet in

thickness and the bottom seam will be only about 3 feet in thickness. These seams will be separated by a clay parting which must be removed by two smaller 18 cubic yard crawler-mounted draglines as depicted in this slide.

This is another slide of the 300 million ton reserve of The Falkirk Mining Company showing the extent of the clay parting over the property.

4. After the strata overlying the top coal seam is removed, a coal drill will next sink blast holes in the coal seam and light explosives will be placed in the holes, as shown. The coal is blasted only just enough to fracture the seam for easy loading.
5. Then a power shovel loads the coal into trucks for transportation to the truck dump hopper and preparation plant facility, as shown here.
6. After the top seam is removed, the clay parting between this seam and the lower seam must then be removed as previously depicted. The bottom seam will then be ripped with bulldozers, blasted where necessary, and loaded with large front-end loaders into haulage trucks.

7. The haulage trucks will discharge into one of three dump hoppers, one or more of which must normally be empty. Primary and secondary crushers under the truck dump hopper will crush the coal to a top size of $1\frac{1}{2}$ inches.
8. From the crushing facility, the coal is fed onto a conveyor belt which transfers the coal to a huge 16,000 ton coal storage silo. It is from the silo that the coal will be fed onto the conveyor extending from the surface facilities of The Falkirk Mining Company to the Coal Creek Station.
9. Of course, after the coal has been extracted, the mining sequence continues with the entire reclamation process as has been previously described.

Although I have depicted the mining and reclamation sequence that will be implemented at The Falkirk Mining Company, these operations obviously will not commence for some time.

Where are we today? We have acquired about 1800 acres of surface lands, complete with a mascot and a farm house, which will be used as a temporary office. This slide presents "Falkirk" a proud collie who is definitely a non-union canine.

We are in the preliminary engineering and construction phases of mine development. On July 14, 1975, The Falkirk Mining Company was

granted a zoning map amendment by the McLean County Planning and Zoning Commission. This authorization permitted the re-zoning of the site of the surface facilities from an agricultural to an industrial classification.

The following series of slides depict the various sites for our proposed:

Railroad branch,

Truck-dump,

Highway underpass,

Dragline erection site,

Access and haulage roads,

as well as the sites for the mine's office, shop, and warehouse buildings.

Further, our staff has been busy in obtaining approvals of the various budgets, specifications, contracts, and purchase orders necessary for this early stage of mine development.

On August 11, 1975, twenty-one trained, non-union employees
were transferred from our Indian Head Mine to The Falkirk Mining Company.
They have been working on the construction of permanent mine access and haulage roads, the establishment of the railroad spur grade, and the initial maintenance and office facilities. These employees are being supervised by skilled, experienced members of our managerial and engineering staffs.

Appropriate permits and licenses are also currently being obtained. These include the license to mine, water permits, reclamation plan approval,

water discharge permits, explosives permits, zoning conditional use and construction permits, and other numerous licenses required to meet Federal, State and local requirements.

A computerized critical path will be established to chart the status of the project. The chronological development of detailed mining plans will be incorporated into this mode to accurately determine potential problem areas and maintain project schedules.

A concise baseline data system of all the areas affected by the mining project is being implemented. This study includes a complete environmental assessment, past and present land productivity studies, climatological data, economic patterns, air and water quality studies, soil types, animal and plant studies, community studies, and land uses.

Notwithstanding the many problems and hurdles lying ahead, The Falkirk Mining Company must and will be ready to produce the tonnage required by the Coal Creek Station prior to the 1978 commencement of operations of that facility. Furthermore, we are confident that we will achieve the lowest possible fuel costs at our operation, with a minimum of environmental and socio-economical impact.

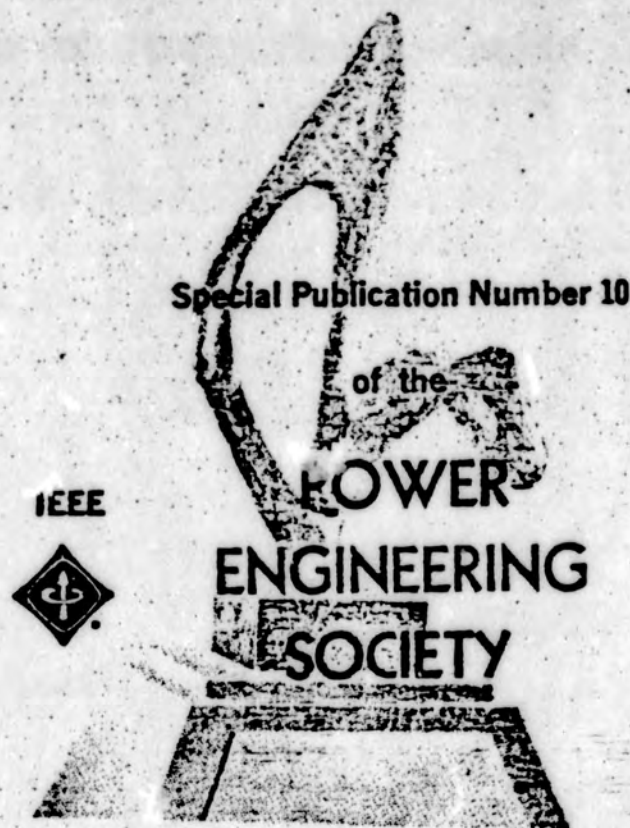
Thank you for inviting me to this fine meeting.

File 020-5

STUDY IN THE USSR OF MEDICAL EFFECTS OF ELECTRIC FIELDS ON ELECTRIC POWER SYSTEMS

Translations from Russian
by
Dr. G. G. Knickerbocker

RECEIVED
JAN 26 1977
Executive Officer
Min. Dept. of Health



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FOREWORD

H. C. Barnes

At the 1972 International Conference on Large High Voltage Electric Systems (Conference Internationale Des Grands Reseaux Electriques a Haute Tension, commonly known as CIGRE) Paper 23.06 by V. P. Korobkova, Yu. A. Morozov, M. D. Stolarov and Yu. A. Yakub of the USSR was entitled, Influence of the Electric Field in 500 and 750-kV switchyards on Maintenance Staff and Means for its Protection. The authors' introduction and conclusions are:

INTRODUCTION

The studies of EHV switchyards electric field effects on human beings have been carried out in the USSR since 1962. Besides the direct influence of the electric field, the influence of electrical discharges appearing when touching different objects, structures, equipment and so on, due to the difference of potentials relative to ground on these objects and on a man is being studied.

The studies have shown that the increase in the operating voltage of the switchyard brings about the increase in the electric field influence. This fact should be taken into account when designing UHV switchyards.

CONCLUSIONS

1. 500 and 750-kV switchyards electric field has an unfavourable effect upon the human organism resulting from the direct field influence after long-time working on it, as well as from the influence of electrical discharges.

2. The degree of the electric field influence upon a man should be assessed by the value of its intensity. At $E \leq 5 \text{ kV/m}$ the field does not influence a man.

3. At the majority of working places at 500 and 750-kV switchyards the electric field intensity considerably exceeds the threshold value. This is why screening is necessary as a means of biological protection.

4. At present the devices for screening working places and special clothing for individual screening are used in the USSR. The latter is not widely applied due to a number of shortcomings.

The discussion of this paper as reported in the proceedings of the 1972 CIGRE Conference is reproduced in Appendix I of this publication.

As a contribution of the IEEE Power Engineering Society toward better understanding of CIGRE Paper 23.06, copies of the medical references of that paper were obtained in the original language and translated by G. G. Knickerbocker, Chairman of the PES Electrical Safety and Life Sciences Subcommittee and members of the Johns Hopkins staff that had conducted a 9-year study of linemen working in electrical fields. These translations were reviewed by 23.06 author Yu. A. Yakub after which he granted permission for IEEE publication. They are contained herein along with other information deemed to be pertinent, including (Appendix II) summaries of later medical papers from the USSR.

No effort is made here to evaluate these papers; that is left to the reader. However, in evaluating these contents, it is important to consider carefully the commentary that follows by the members of the Johns Hopkins Hospital staff, particularly when considering the influence upon persons who may be in the vicinity of lines rather than in substations to which access is restricted to authorized personnel.

ADDENDUM

(To Foreword)

On February 18-19, 1975, the USA-USSR Working Group on UHV Transmission met in Washington, D.C. Papers presented by the USSR representatives included one entitled:

ELECTRICAL FIELD AS A PARAMETER CONSIDERED IN DESIGNING ELECTRIC POWER TRANSMISSION OF 750-1150 KV; THE MEASURING METHODS, THE DESIGN PRACTICES AND DIRECTION OF FURTHER RESEARCH

Yu. I. Lyskov, Yu. S. Emma—the "Energoset'proekt" Institute—M. D. Stolyarov—ORGRES

This established higher acceptable gradient standards for transmission lines in accordance with these direct quotations:

In designing the O. H. 750-1150 kV line, considering that cumulative effect of the field due to an infrequent and nonsystematic exposure of the local population and

the agricultural workers can practically be disregarded, as permissible magnitudes of the field intensity the following higher standards were accepted:

20 kV/m for difficult terrain,
15-20 kV/m for non-populated regions,
10-12 kV/m for road crossings.

The permissible field strength must not be exceeded at the center of the span at the height of 1.8 meters above ground and at the lowest sag (at the maximum 15 year temperature).

The permissible values of field intensity were chosen with consideration of favorable operating experience in over 150,000 km/years in O. H. 500 kV lines, for which the designed field intensity is for similar conditions from 10 to 14 kV/m.

Comment by Johns Hopkins Study Team

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This series of Russian medical papers contains much subjective material which makes it difficult to reach any firm conclusions from this work. Notable especially is the absence of comparable data on workmen not exposed to electric fields. As we have commented elsewhere, analysis of data that does not take into consideration working conditions and social, political, and environmental influences must be viewed with great caution.

We can only reaffirm the conclusions from our project that we did not find any disease or any ill effect from high voltage line exposure in a study of ten linemen over a period of nine years beginning in 1963 and dealing with system voltages up to and including 765-kV. Further, we have ascertained that these ten linemen are at present time (September 1974) all working

and are healthy and have lost no time from work. Significant is the fact that these men worked in field gradients far in excess of any encountered at ground level.

It should be understood that our study involved exposures many times more severe than that reported by the Russians as our study was concerned with linemen working adjacent to or in direct contact with energized conductors whereas the Russian workers were exposed to lower fields at ground level. Significant to the subjectivity of the data of 23.06 is this statement by one of the Russian authors in a personal letter. "The staff maintaining 500 and 750-kV lines in the USSR in contradiction to the staff maintaining substations of the same voltages do not complain of their health changing for the worse under the influence of the electric field".

THE STATE OF HEALTH OF PERSONS WORKING IN THE ELECTRIC FIELD OF OUTDOOR 400 AND 500 kV SWITCHYARDS

P. Asanova and A. I. Rakov, Leningrad

It is worthy of note that 1/3 of the men examined in the age of 30-40 years complained of sexual weakness, which developed after 8 to 10 months of work under the conditions of influence of high voltage electric fields. In the histories of these people there was no indication of disease of the urinary tract, venereal disease, psychotic trauma, or other aggravating factors. Besides this, the examinees complained fairly frequently of palpitations, painful phenomena in the cardiac region (piercing, aching, squeezing), irritability, and poor appetite after work.

It must be noted that we carried out the medical examinations in summer. Therefore, meteorological factors might play a role in the character of the complaints. Taking this into consideration, we utilized data from medical examination of the substation personnel done in local polyclinics in different seasons in the preceeding two years. Analysis of these data showed that these same neurological disorders were noted in the examinees in the autumn and winter.

Neural pathology was diagnosed in 28 of the subjects. In more than half of the examinees (in 26 of 45) functional disruption of the central nervous system was determined, appearing clinically chiefly in the form of autonomic disfunction and significantly less often (in 6 cases) in the form of neurasthenic syndrome. In the usual neurological examination, in a majority of the persons, the phenomenon of autonomic disfunction was of moderate degree. Thus, in these there was noted: stable red dermograph, instability of the pulse and arterial pressure, hyperhidrosis in the armpits and on the palms, fine tremors of the extended hand. Only in four persons were vasomotor and secretory disorders of a more marked character.

The neurasthenic syndrome established in four examinees might be evaluated as hypersthenic. These people complained of headaches, sluggishness, fatigue, irritability, uneasy superficial sleep, and sexual weakness. Objectively, enhanced tendon reflexes with an extended range, coarse tremor of the fingers, mild instability with closed eyes, and higher emotional excitability were noticed in these persons. These symptoms match moderate autonomic disorder. Moreover, in two men over 50, initial signs of sclerosis of vessels of the brain together with arteriosclerotic cardioclerosis was observed. Symptoms of organic damage to the nervous system were not seen. It must be noted that we were not successful in establishing increased neurological complaints and neuropathology with increased work experience under the influence of high voltage electric fields. More marked neurodynamic changes were seen in maintenance people who had the greatest daily exposure to the electric field.

In examination of internal organs, pathology was noted in 18 persons. Diseases of the cardiovascular system were the most frequently encountered (in 14 persons). Among them,

the neurogenic state of hypertensive disease was established in four men, aged 35-37, with 2 to 4 years work experience in the electric field. Arteriosclerotic cardiosclerosis was noted in 3 examinees over 50. In 6 persons with etiologically aggravated history, myocardial dystrophy was found (In 4 of these their histories showed chronic tonsillitis in 2—alcohol abuse). A mitral defect (compensated) was found in one.

Studies of the cardiovascular systems of substation personnel revealed a lability of pulse and arterial blood pressure. Bradycardia was noted in 12 persons, tachycardia in 5. Upon blood pressure measurement, hypotension was noted in 7 people, hypertension in 4. Studying the data of medical examinations for 1961-62, it may be noted that lowered arterial pressure in 14 persons, hypertension in 2, were observed previously among the examinees. Thus, besides frequently noting variance of pulse toward bradycardia in substation personnel, transient hypotension was observed in half of the cases. The tendency toward hypertension was observed only in isolated individuals.

Electrocardiographic studies showed sinus bradycardia in 14 persons, slowed atrial and ventricular conduction in 10. Besides this diffuse changes of the myocardium were seen in some persons. The observation of ECG changes compels us to regard them with great caution and to explain whether they were temporary and reversible and whether they will not lead to further, more marked organic damage to the regulatory apparatus of the cardiovascular system and cardiac musculature. It is not possible to answer these questions at this time, in as much as more extensive studies and further dynamic observations are needed.

The influence of high voltage electric fields of commercial frequency upon the human organism has received little study. But this question is quite pertinent, for the contingent of people working under the influence of such fields increases all the while. Considering the importance of the clinical elucidation of this question, we carried out a medical examination* of the personnel of 400-500 kV substations (at two hydroelectric stations on the Volga) under field conditions.

The group examined by us consisted of 45 persons (41 men and 4 women). They were, by profession, mainly electricians (maintenance or attendants) and to a lesser number, signalmen and secondary personnel. They were distributed by age in the following fashion: up to 30 years of age—10 persons, 30-40 years—29 persons, over 40 years—6 people. Substation experience consisted of: 9 persons up to one year, 20 persons from one to three years, 11 from three to five years, more than five years—5 persons. Thus, the examined group basically consisted of middle aged people (to 40 years) with relatively short employment in an electric substation.

The average daily exposure to the electric field was the most (5 hours) in maintenance personnel. For attending personnel, it was, on the average, two hours a day. Signalmen and secondary personnel were not in the field constantly, nor for prolonged periods. It is clear that substation personnel, when

*A therapist, neuropathologist, and oculist took part in the medical examination.

on the territory of 400-500 open switching structures, are subjected to the action of high voltage of commercial frequency. As a result, a current, dependent upon the capacitive coupling of the person with the parts under working voltage and ground, flows through the worker.

Measurements by S. A. Levedev (Leningrad Institute of Labor Protection) showed that, depending on his location in the switching station, a person sustains an electric field of varying intensity. The highest potential of the field at the height of the person reaches 26 kV, the average potential is 14-18 kV. Consequently, the strength of the current flowing through the person maximally, reaches 230 microamperes; but the current strength corresponding to the average potential at the height of man equal 125-115 microamperes. Maintenance personnel working in the switching areas on disconnected equipment sustain the effect of an electric field with an average potential of 2 kV. The strength of the current flowing through the body is 15 microamperes. The maximum potential which maintenance men experience on disconnected equipment reaches 4 kV, which corresponds to a current strength of 35 microamperes.

In substation personnel we carried out a complete clinical study of peripheral blood, roentgenography of the organs of the chest and electrocardiography. First of all, our attention was drawn to the frequency of subjective disorders. Some kind of complaint was expressed by 41 of the 45 examinees. Complaints of a neurologic character (headache, sluggishness, fatigue, sleepiness) occupied first place by frequency. Thirty-seven people presented these. Then complaints of disrupted activity of the digestive tract and cardiovascular system followed.

Neurological disorders were variable. Usually they occurred at the time the person was in the electric field, in the middle or at the end of the working day, and disappeared relatively quickly after the person left the field and rested. Headaches had a quite variable character (prolonged, pulsating, compressing) with varying localization, but most frequently were noted as pain in the temporal and parietal regions. The intensity of the headaches increased in proportion to the duration of time that personnel were in the electric field. In only a few persons, were headaches accompanied by nausea. Some people noted that after work sleepiness and sluggishness de-

veloped so strongly that upon returning home, they were not in any state to engage in any sort of activity and were forced to go to bed. After sleep, as a rule, the unpleasant phenomena disappeared.

Variability of the pulse and arterial pressure, and ECG changes in persons not having organic cardiovascular disease are provisionally considered as functional disorders of the cardiovascular system. They are evidently connected with disorders of central autonomic regulation. The impression is created that changes in the cardiovascular system are encountered more frequently and are more marked in persons systematically subjected to the influence of electric fields (maintenance personnel), than those exposed sporadically (signalmen, attendants).

Regarding changes in other organs, diseases of the digestive tract were noted in 6 people (chronic gastritis, colicystitis). Ophthalmological examinations did not reveal any sort of changes in the organs of sight. A series of changes were seen in studies of peripheral blood. Moderate thrombocytopenia and changes of the white blood cells in the form of moderate neutrophilic leukocytosis or leukopenia with neutropenia were most frequently encountered. Lymphocytosis and monocytosis were also observed. Changes in red blood cells were seen more rarely, and here a tendency toward reticulopenia and moderately lowered hemoglobin and erythrocytes were noted. A retarded sedimentation rate (from 1 to 3 mm) was found in 19 examinees. It is difficult to explain this now, for this requires more extensive studies (studies of the functional state of the liver, blood protein fractions, etc.). Marked spherocytosis was found in 17 of 28 persons in which cytometric studies of erythrocytes were carried out.

Thus, data of these examinations gives leave to assume that being in a high voltage electric field of commercial frequency is an adverse influence upon the working person. This is manifest by disorders of the functional state of the nervous and cardiovascular systems. Qualitative and quantitative changes of peripheral blood also merit attention.

For final resolution of the question of the nature of the influence of high voltage electric fields, further dynamic observations of the workers examined by us and an accumulation of more widespread material by examination of personnel of other similar substations are necessary.

A PHYSIOLOGICAL ASSESSMENT OF THE WORK CONDITIONS IN 400-500 kV OPEN SWITCHING YARDS

T. E. Sazonova

With the advent of the transmission of high voltage 50 Hz ac (400-500 kV) complaints of a degrading state of health began to occur from the attending personnel of open switchyards, specifically fatigue, somnolence, and headache. There are no data on the biological effects or the extent of harm of high voltage 50 Hz electric fields in either the Soviet or the foreign literature. A physiological study of the attending personnel of several 400-500 kV substations was carried out to elucidate the effects of such fields.¹

Current switching structures are located along transmission lines on open ground about 1000 square meters in area. In the work area of switching structures a nonuniform electric field of significant intensity is present. While working under these conditions an electric current passes through the person, the magnitude of which is established by the potential of the electric field at the given point and the capacitance of the person relative to ground. Measurements showed (1) that attending personnel are subjected to the action of electric fields with a minimum potential of 2-4 kV, an average of 12-16 kV, and a maximum of 20-26 kV. With a good connection of the person to ground, the currents passing through the body at these voltages are, respectively, 15-35 microamperes, 100-130 microamperes, and 180-230 microamperes.

Attending personnel of open switchyards consist of maintenance and operating crews. Workers from both groups carry out light work with elements of intellectual and physical stress. Auxiliary and relaying people from the operating crews work in closed quarters which are located on the switchyard site in places with a minimal electric field. Attendants make rounds of the switchyard and are in places with minimal, average, and maximal fields.

Maintenance personnel may work in any place in the switchyard. Repair of air breakers, disconnects, current transformers, etc. is carried out under partial shutdown of equipment. With such work, personnel are subjected to a weak electric field, but the current of 15-35 microamperes flows through these people for long periods of time. Maintenance personnel sometimes work close to connective machines and devices of the switchyard located under high voltage (for example, repairs to disconnects carried out without shutting down the device). In these cases, the intensity of the electric field at the work site reaches the maximum values.

Two groups were formed for the physiological studies. Persons working under electric field exposure of not more than two hours daily were in Group I (operating personnel) while those who were exposed not less than five hours daily were in Group II (maintenance personnel). In all, 54 people were studied: 29 people from the operating crews and 25 people from the maintenance crews. The breakdown of work experience in electric fields is as follows: up to 1 year—12

people, from 1 to 3 years—22 people, from 3 to 5 years—15 people, and over 5 years—5 people. The ages of the subjects fell into three groups: under 30 years—17, from ages 30 to 40 years—33, and older than 40 years—4.

The following indices were determined in order to evaluate the functional state: temperature, pulse, arterial pressure in the humeral artery, latency and quantitative error of the speech-motor reaction, critical flicker frequency, and the strength-duration curve and optimal stimulation frequency of the adductor muscle (adductor pollicis) of the thumb of the right hand. The rate of movement of the thumb was determined by the tetanizing curve which may be directly characterized by the tangent of the angle of inclination of the ascending portion of the tetanizing curve to the initial horizontal line. All other conditions being equal, the lower the rate of movement, the greater the tangent of the angle of inclination of the tetanizing curve to the initial line.

The temperature of the body, pulse, and blood pressure reflect the status of autonomic function. Critical flicker frequency characterizes the functional mobility of the eye, while the strength-duration curve and the optimum-pessimum frequency of stimulation of the adductor pollicis characterizes the excitability and functional mobility of motor systems. Higher nervous activity was studied by the Ivanova-Smolenskii method.

The results of these studies were worked up statistically, according to the degree of probability P of the difference between means of compared values. A result was considered justified for P of 0.05. With such a value of P , the assurance of a difference between two compared series is 95%.

A comparison of the average arithmetic data for the six days of the week was made; it consisted of Group I before and after work, Group II before and after work, Groups I and II before work and Groups I and II after work. Analysis of the results permitted the following observations: 1.) what functional changes arose in the course of the working day in persons for various durations of work under the influence of the electric field, 2.) the intensification, if any, of functional changes over the period of one work week, and 3.) any differences in functional changes in persons of the two groups for various work durations under the influence of the electric field.

Indices of Autonomic Functions

Every day of the work week exhibited a well-defined pattern of functional changes. Therefore, the results of the studies of just one day (a Wednesday) are given.

Body temperature, pulse, and diastolic and systolic arterial blood pressure of persons in Groups I and II are given in Table 1. Body temperature in persons of both groups at the beginning of the work day was in the normal range — Group I, 36.6 ± 0.05 C — Group II, 36.8 ± 0.08 C. By the end of the work day it was still in the normal range for persons of Group I (36.9 ± 0.06 C), but those in Group II, were higher (37.1 ± 0.06 C).

¹ Drs. T. P. Asanova and A. M. Rogov of the Institute of Hygiene and Industrial Medicine (Leningrad) together with physicians of the local polyclinics carried out medical examinations on (attending) personnel of these stations.

TABLE I
Indices of Autonomic Function

Index	Time Measured	Group I			Group II			$M_1 - M'_1$	P	$M_2 - M'_2$	P	$M_3 - M'_3$	P
		$M_1 \pm m_1$	$M_2 \pm m_2$	$M_3 \pm m_3$	$M'_1 \pm m'_1$	$M'_2 \pm m'_2$	$M'_3 \pm m'_3$						
Body Temperature	before work	36.6 $\pm$ 0.05	-	-	36.8 $\pm$ 0.08	-	-	-0.2	0.061	-	-	-	-
	after work	36.9 $\pm$ 0.06	-	-	37.1 $\pm$ 0.06	-	-	-0.2	0.093	-	-	-	-
Pulse Beats/Min	before work	68 $\pm$ 2.4	117 $\pm$ 2.4	67 $\pm$ 1.5	69 $\pm$ 2.7	107 $\pm$ 5.5	70 $\pm$ 2.6	-1	0.383	+10	0.055	-3	0.159
	after work	73 $\pm$ 2.0	115 $\pm$ 2.6	75 $\pm$ 2.1	67 $\pm$ 2.0	98 $\pm$ 5.0	69 $\pm$ 2.4	+6	0.002	+17	0.002	+6	0.036
Systolic Arterial Pressure mm Hg	before work	121 $\pm$ 2.0	140 $\pm$ 2.8	119 $\pm$ 2.9	107 $\pm$ 3.4	126 $\pm$ 4.4	101 $\pm$ 3.6	+14	0.001	+14	0.004	+18	0.001
	after work	120 $\pm$ 2.5	142 $\pm$ 2.9	118 $\pm$ 2.8	108 $\pm$ 2.0	130 $\pm$ 4.7	97 $\pm$ 2.6	+17	0.001	+12	0.014	+21	0.001
Diastolic Pressure mm Hg	before work	60 $\pm$ 1.9	69 $\pm$ 1.8	75 $\pm$ 1.9	51 $\pm$ 3.5	53 $\pm$ 4.1	61 $\pm$ 3.9	+6	0.067	+16	0.001	+14	0.001
	after work	60 $\pm$ 1.7	61 $\pm$ 1.9	72 $\pm$ 1.7	52 $\pm$ 2.9	50 $\pm$ 4.2	55 $\pm$ 2.7	+8	0.009	+11	0.009	+17	0.001

M_1, M'_1 : Average value before squatting.

M_2, M'_2 : Average value after squatting.

M_3, M'_3 : After 5 minutes of rest.

$m_1, m_2, m_3, m'_1, m'_2, m'_3$: Average error

(the functional state of the cardiovascular system was evaluated by means of a functional test - 30 squats)

Pulse and arterial pressure of both groups did not substantially change in the course of the working day. The comparison between groups showed that after work the pulse and arterial pressure in the workers of Group II was lower than those in Group I. With this, the pulse in Groups I and II and the arterial pressure in Group I oscillated in normal limits but the arterial pressure in Group II was lower than normal. For example (see Table I), at the beginning of the work day in tests (before squatting) the systolic pressure was 117 ± 3.4 mm Hg, diastolic pressure 54 ± 3.5 mm Hg; correspondingly at the end of the working day 103 ± 2.0 mm Hg and 52 ± 2.9 mm Hg.

The excitability and speed of reaction of the neuromuscular organs of the hand in response to stimulation with an electric current of the adductor pollicis muscle were indicators of the functional state of the central nervous system and higher nervous activity. Excitability of the neuromuscular apparatus of the hand was evaluated by the strength-duration curve; the functional mobility by the tetanizing curve.

The curves characterizing excitability are given in Figure 1; Figure 2 is the functional mobility of the neuromuscular apparatus of the hand of persons of Group II. Analogous curves for operating personnel are not given because they coincide with the corresponding dotted lines given in Figures 1 and 2. To achieve the threshold effect (a hardly noticeable movement of the thumb) in maintenance personnel measured after work, less amplitude of the stimulating current was required than before work. The difference was expressed more strongly with the longer stimulating impulses exceeding 0.11 milliseconds and weaker with durations from 0.02 to 0.11 milliseconds. This gives evidence to the fact that the excitability of the neuromuscular apparatus by the indicator of long duration threshold (Nasonov's terminology (2)) changed more strongly than the index of short duration threshold. It is known that short duration threshold characterizes the excitability of tissue while the prolonged duration threshold characterizes their resistance. Consequently the excitability of the neuromuscular apparatus at the end of the working day in comparison with the beginning was elevated, but the resistance

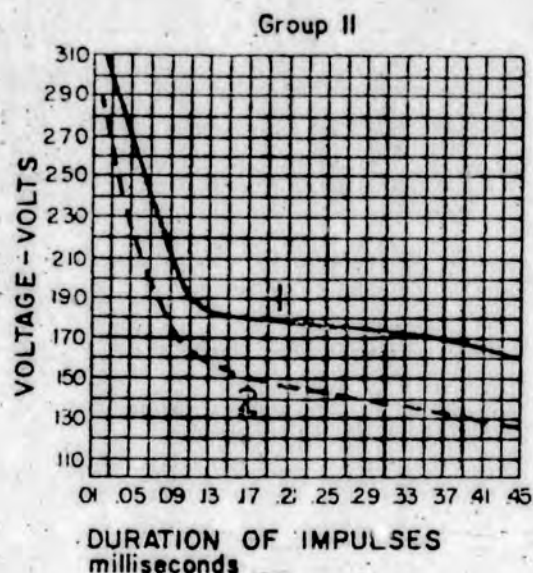


Figure 1. Excitability of neuromuscular apparatus of the hand. 1 - Before work. 2 - After work.

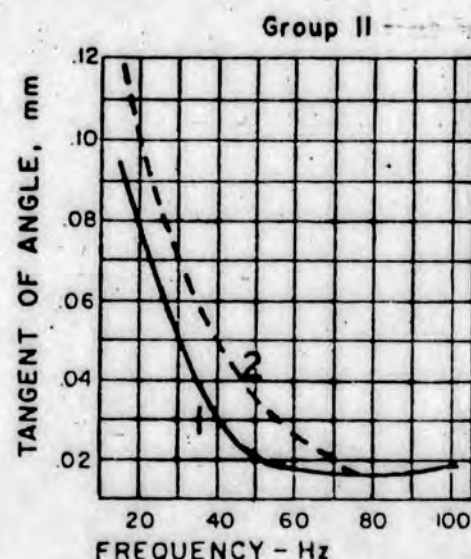


Figure 2. Dependence of tangent of angle of inclination of tetanus curve to initial line on frequency of stimulating current. 1 - Before work. 2 - After work.

TABLE 2
Indices of Speech-Motor Reactions

Conditional Stimulus	Group	Latent Period of Reaction (seconds)				Errors (percent)			
		$M \pm m$	$M' \pm m'$	$M-M'$	P	$M \pm m$	$M' \pm m'$	$M-M'$	P
Bell	I	0.51 ± 0.08	0.52 ± 0.15	-0.01	0.461	0	0	0	0
	II	0.49 ± 0.06	0.53 ± 0.09	-0.05	0.309	0	0	0	0
Red Light	I	0.52 ± 0.16	0.56 ± 0.11	-0.04	0.421	0	0	0	0
	II	0.52 ± 0.19	0.82 ± 0.11	-0.30	0.081	0	0	0	0
Green Light	I	0.78 ± 0.19	1.09 ± 0.14	-0.31	0.097	9.1 ± 1.6	12.4 ± 1.1	-3.3	0.135
	II	0.76 ± 0.20	1.31 ± 0.12	-0.55	0.009	12.6 ± 2.6	27.4 ± 3.2	-14.8	0.001
Blue-Green Light	I	0	0	0	0	8.3 ± 1.0	10.7 ± 2.1	-2.4	0.159
	II	0	0	0	0	14.1 ± 2.3	32.4 ± 2.8	-18.3	0.001

M : Average value before work.

M' : Average value after work.

m, m' : Average error.

to the action electrical current was diminished.

Even the indices of functional mobility of the neuromuscular apparatus changed (see Figure 2). The speed of movement of the thumb for frequencies of excitation from 20 to 70 Hz at the end of the working day in comparison with the beginning was lowered while at the higher frequencies it remained unchanged. In operating personnel the functional state of the neuromuscular apparatus of the hand during the course of the working day did not change.

The functional state of visual receptors judged by the index of critical flicker frequency essentially did not vary with various duration of work under conditions of the action of electric fields. Critical flicker frequency in persons of Group I at the beginning of the work day varied from 34.4 ± 1.2 to 37.1 ± 0.8 Hz, at the end of the working day from 32.1 ± 1.1 to 34.7 ± 1.1 Hz, correspondingly in persons of Group II at the beginning of the working day from 33.0 ± 1.4 to 39.1 ± 0.7 Hz and at the end of the working day from 31.6 ± 1.5 to 40.2 ± 1.3 Hz.

Higher nervous activity was characterized by the latent period of the speech-motor reaction and equal quantitative error in response to positive signals (bell, red light, green light) and to negative (differentiating) signal (blue-green light). The latent time of reaction and the quantitative error of persons of Groups I and II are given in Table 2. The latent time of reaction of workers in both groups at the end of the working day increased: in Group II this was expressed more markedly than in Group I. For example, the latent time of reaction to green light in persons of Group I at the end of the working day in comparison with the beginning increased from 0.78 ± 0.19 to 1.09 ± 0.14 seconds, but in Group II the increase was from 0.76 ± 0.20 to 1.31 ± 0.12 seconds.

The quantitative error in both groups increased by the end of the working day just as the latent time of reaction did. It was more noticeable in Group II than in Group I. The increase of the latent time of reaction gives evidence of a developing inhibition in the cortex of the brain but an increase in the quantitative error gives evidence of a weakening of the concentration of the processes of excitation and inhibition. These changes of neurodynamics in persons of Group II were significantly stronger than in Group I.

If we taken into account that fatigue is connected with the development of inhibition in the higher sections of the central nervous system then we may draw the conclusion that prolonged action of the electric field evoking inhibitions in the cortex of the brain favors the development of fatigue.

As a result of medical studies in attending personnel a definite direction for changes in the central nervous system was established. These changes appeared in the form of autonomic disfunction (greater variability of pulse and arterial blood pressure, predominantly toward bradycardia and hypotonia) and neurasthenic syndrome. Symptoms of organic disfunction as a result of the action of electric fields while working on 400-500 kV switchyards was not established.

The results of physiologic studies agrees with and supplements the data of medical observations. The physiological studies showed vagotonic changes of the cardiovascular system, weakening of the processes of thermal regulation, lowering the resistance to the action of electric currents and functional mobility of the neuromuscular apparatus of the hand, and a weakening of neurodynamic processes in the cortex of brain. The functional changes recounted above were evident in maintenance personnel (prolonged work in the electric field no less than five hours per shift) and they did not appear or appeared weakly in operating personnel (prolonged work in milliseconds. This gives evidence to the fact that the excit- the electric field of not more than two hours per shift). This permits us to say that the extent of functional changes in the organism are in direct dependence upon the duration of work under conditions of the action of electric fields, i.e., changes evoked by the field proceed in a cumulative fashion. Earlier such a dependence was expressed in experiments on animals with the study of the action of the electric fields of a frequency of 50 Hz on the efficiency of motor organs(3).

Considering that the work experience in 400-500 kV switchyards in a majority of the individuals observed was relatively short—up to five years, the appearance of functional changes necessarily must be viewed as the beginning of an unfavorable action of the electric fields. In connection with this it is necessary at first to carry out possible measures for protection of attending personnel in 400-500 kV switchyards from the prolonged action of electric fields and secondly to

continue the studies for establishing limits of permissible intensity of electric fields of commercial frequency.

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DEVICE FOR THE MEASUREMENT OF INDUSTRIAL FREQUENCY ELECTRIC FIELD INTENSITY

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Ultra high voltage transmission lines of 500 kV and higher have found wide application for transmission of electrical energy at great distances in the Soviet Union. Studies showed that in the work regions of these transmission lines a strong electric field with intensities to kV/meter arise. It is known that prolonged exposure of a person to an electric field of high intensity is not without effect upon his health (1).

Special devices are required for studying work conditions of attending personnel of these transmission lines which permit measurement of the intensity of the electric field close to high voltage apparatus. Until recent time there were no such instruments. The existing instrument INEP-2 (2) has a 1.5 meter long remote pickup connected with ground and therefore its use on high voltage transmission lines is prohibited by the electrical safety rules.

Other methods of evaluation of the electric field at the work site on transmission lines by means of measurement of the potential field relative to ground by an electrostatic voltmeter or the determination of the magnitude of displacement current through a person by a microammeter (3) does not give sufficient information for complete characterization of the action of the field on a person. Besides this, these methods are quite time consuming inasmuch as they require good electrical isolation of the man from ground which is very difficult to accomplish in practice, especially in measurements on transmission line towers.

One of the basic requirements set down for an instrument for direct measurement of the intensity of the field on transmission lines at close range is that its circuit antenna and case not be electrically connected to ground. In the INEP-50 instrument developed at the All Union Scientific Research Institute for Labor Protection in Leningrad this requirement is guaranteed by the use of a handle of insulating material 250 mm in length.

The operator holds the instrument by the handle and inserts it into the measured area (Fig. 1). In the process of making the measurement the instrument is oriented to give the greatest deflection of the needle which corresponds to the maximum intensity of the field in the region in which the instrument is located. The instrument has the dimensions 150 mm X 90 mm X 50 mm and weighs 600 grams. Power is

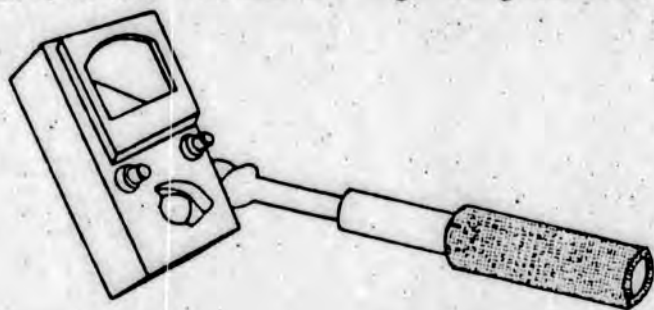
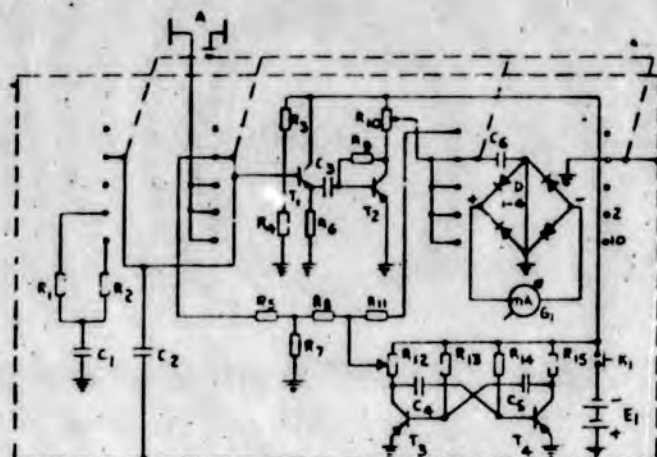


Figure 1. An instrument for the measurement of the intensity of electric fields of 50 Hz.



$R_1, R_7, R_9 = 100K; R_2 = 6.2K; R_3, R_4 = 300K; R_6 = 10K; R_5, R_{10} = 4.7K;$
 $R_8, R_{13}, R_{14} = 51K; R_{11} = 20K; R_{12} = 1K; R_{15} = 2.2K; C_2 = 30pF;$
 $C_1, C_3, C_6 = 20mfd; C_4, C_5 = 0.25mfd;$ Transistors T_1 thru T_4 = Type
 MP-41A (Soviet NPN transistors); Diodes D_{1-4} = Type D-11 (Bridge);
 Battery $E = 4.5V$, Meter = Type M-4204 - 10 Duo

Figure 2. A schematic of the instrument.

supplied from one 4.5 volt battery. Fields from 1-1000 kV/m are the limits of measurement of electric field intensity. Error of measurement does not exceed 20% of the actual value of the measured magnitude.

Description and Principles of Operation of the Instrument

The schematic of the instrument (Fig. 2) consist of four basic sections:

1) The input network is an antenna A in the form of a dipole made of two metal plates of dimensions 25 mm X 40 mm located on the top and bottom of the body of the instrument, two resistors R_1 and R_2 with which the input of the instrument is shunted for expanding the limits of measurements, and a capacitance C_1 for symmetrizing the capacitance between antenna plates and the body of the instrument.

2) A two-stage ac amplifier consists of transistors T_1 and T_2 . The first stage is an emitter-follower for increasing the input resistance; the second is a common-emitter with gain control R_{10} in the collector circuit of transistor T_2 . The gain of the amplifier is 40.

3) A full-wave rectifier is accomplished with a bridge of semi-conductor diodes D_{1-4} . One diagonal of the bridge is connected to the output of the amplifier through a decoupling capacitor C_3 , and the other diagonal is connected to a microammeter G_1 .

4) A generator of sustained oscillations (50 Hz) is accomplished by a multi-vibrator, utilizing transistors T_3 and T_4 . The generator is used for automatic calibration of the instrument before measurements.

The principle of the instrument is based on the action of an ac electric field in the antenna dipole which induces an electromotive force as a consequence of which a signal is produced at the input of the amplifier. In accordance with the equivalent

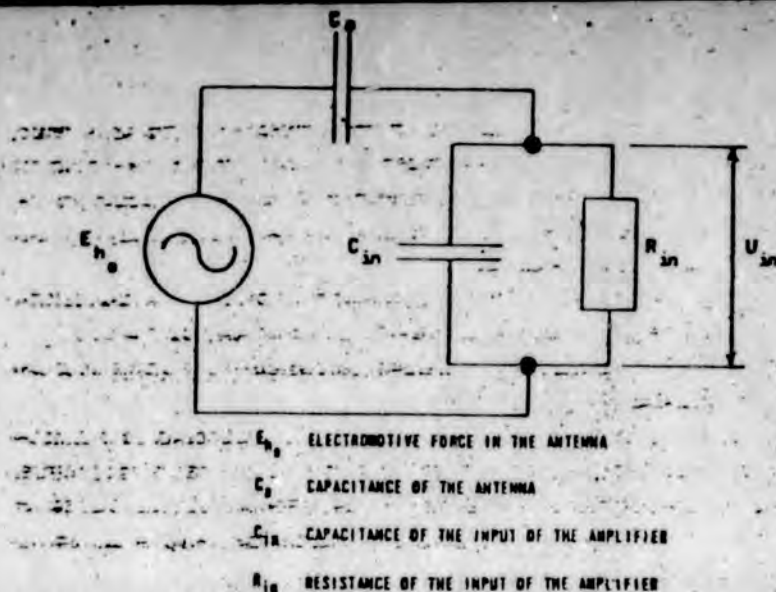


Figure 3. Equivalent diagram of the input circuit of the instrument.

diagram of the input circuit of the instrument (Fig. 3) the voltage of the signal at the input of the amplifier U_{in} is proportional to the effective value of the intensity of the electric field E

$$U_{in} = \frac{E h_e C_a}{(C_{in} + C_a) \sqrt{1 + \frac{1}{W^2 (C_{in} + C_a)^2 R_{in}^2}}}$$

where

h_e is the effective length of the antenna

C_a is the capacitance of the antenna

C_{in} is the input capacitance of the instrument

W is the angular frequency

R_{in} is the input resistance of the instrument.

The signal amplified by transistors T_1 and T_2 (see Fig. 2) is applied through potentiometer R_{10} and blocking capacitor C_6 to the measurement bridge D_1 . The scale of an indicating microammeter is graduated from one to ten kilovolts per meter. The upper limit of measurement may be multiplied by a factor of two or ten by switching resistances R_1 or R_2 in parallel to the input.

Calibration of the Instrument

In the instrument there is a special calibrating generator of transistors T_3 and T_4 for accomplishing calibration of the instrument which establishes the coefficient of amplification before measurement. Resistances R_{12} through R_{15} and capacitances C_4 and C_5 are chosen such that the signal frequency is 50 Hz.

Calibration of the instrument consists of initially applying the signal from the generator to the measurement bridge through resistance R_{11} . The magnitude of this resistance is at least an order of magnitude greater than the sum of the resistances of the diode bridge and the coil of the indicating ammeter. This eliminates the error in establishing the calibrating potential of the generator because of temperature changes

of the resistance of the semi-conductor diodes of the bridge. The necessary voltage at the output of the generator is set according to a mark on the scale of the instrument by means of potentiometer R_{12} .

Then the output of the generator with fixed voltage is connected to the amplifier through resistance R_5 , the magnitude of which by many times exceeds the input resistance of the amplifier. This insures a constant current in the circuit during possible temperature changes of the input resistance of the semi-conductor amplifier. With the aid of the mark on the scale of the instrument the required coefficient of amplification is established by adjustment R_{10} . By such a calibration, the indication of the instrument will correspond to its initial calibration in a uniform electric field of known intensity.

Initial calibration is carried out with adjustment of the instrument and consists of the device being placed on an insulating stand in the uniform electric field of a plane capacitor consisting of two metal plates 2.5×2.5 meters separated by a distance of one meter.

A source of regulated high voltage up to 20 kV is applied to the plates. For a given case the intensity of the electric field between the plates is $E = U/L$ kV/m where U is the voltage on the plates in kilovolts and L is the distance between the plates in meters.

Calibration under the stated conditions simultaneously takes into account the distortion of the uniform electric field because of insertion of the instrument into it. It is necessary to note that uniformity of the electric field in the zone in which the instrument is placed is a necessary condition for correct measurement of the intensity. Conditions of uniform electric field at the point of measurement on high voltage transmission lines is practically always fulfilled with the physically small instrument INEP-50. Actually, data from calculations and measurements of the distribution of the electric field on high voltage lines (4) shows that field intensity is proportional* to the square of the distance from the source of the field (conductor, connecting bus, etc.). The relative magnitude of the changes of intensity of the field for increases of the distance from the source S to the magnitude of the linear dimensions of the instrument ΔS is equal to $\Delta S(d/ds)(1/S^2)S^2 = -2\Delta S/S$.

At the present time an experimental group of INEP-50 instruments is being prepared at the SKB Institute. Preliminary tests of the instrument field conditions were carried out on transmission lines of the distribution centers of the Leningrad power system and the Moscow power system. Results of the test showed that the instrument is simple and convenient to use. No more than five minutes were spent making the necessary measurements at one work site (ten measurements). Calibration of the instrument does not need to be carried out before each measurement but after ten to fifteen minutes of use.

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ELECTRICAL DISCHARGE INFLUENCE UPON A MAN

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While working in intense electric fields, in addition to the direct action of fields on man there is the action of electric discharges occurring at the moment a person carrying an electric charge contacts grounded construction or at the moment when a man well-connected to ground, contacts a charged object. In both cases the person may experience a painful pricking sensation.

The object of this present work was the study under laboratory conditions of the action of electric discharges on man arising during work in strong electric fields. The potential on the person working in such fields reaches 10 kV, and the capacitance of a man is 70 to 100 picofarads. The energy of the electric discharge with a potential of 10 kV and a distributed capacitance of 100 picofarads is equal to 5×10^{-3} joules; the duration of the impulse 8×10^{-8} seconds.

Electrical discharges were obtained by means of a special high voltage device. The influence of electrical discharges was studied on four subjects (40 experiments). Two series of experiments were carried out. In the experiments of both series electrical discharges with equal energies were applied but the sequence of application of impulse discharges was varied.

It was observed at the beginning of the action of the electrical discharges that there was a marked increase in excitability in the cortex of the brain, depression of alpha rhythm in the lobar regions of the brain. Simultaneously in other regions on closing the eyes the latent period reaction increased and then decreased upon opening the eyes. For this the ratio of the latent period of the first reaction to the second reaction increased by $1\frac{1}{2}$ to 2 times. Besides this the action of the discharge caused an observable shift of the bilateral focus of activity in the cortex: the right hemisphere rather than the left became dominant.

In experiments of the first series (discharge of impulses applied with an interval of 20 seconds) at the time of action of

the discharges the bilateral focus of the activity of the brain changed in one or two regions. In the second series (discharge of impulses applied with an interval from 1-30 seconds) the activity changed in all regions of the brain. In control experiments the bilateral focus of activity of the brain did not change.

Electrical discharges evoke changes even in autonomic function. In experiments of the first series the rate of pulse and respiration did not change, but in the second series the pulse became slower and respiration became more rapid. Variability of pulse and respiration increased. The marked increase in variability of the rate of pulse and respiration (by $1\frac{1}{2}$ to 2 times) is evidence of the lowering of functional stability of the organism. Consequently the action of electrical discharges is not without effect upon a person. With the action of discharges the excitability in the cortex of the brain increased in particular in regions "responsible" (according to the neurologic conception of E. K. Sepp (Luria, A. G., Tsvetkovs, L. S.)) for motor logic-function as the interchangeability of the hemispheres was intensified. This gives evidence of the intense work of the brain similar to that which takes place at the time of fatigue in overcoming the "dead point" in the process of exercise (Pavlova, L. P., Tochipaw, K. S.). Variability of pulse and respiration was markedly increased.

It must be supposed that with increased voltage on active transmission lines, the intensity of the electric field in the working region will increase and consequently the frequency of occurrence of electrical discharges and the discharge energy will increase. Evidently, for work in such fields, frequent sudden electrical discharges evoking painful sensations may lead to the occurrence of stagnant foci of excitability in the cortex and disruption of the equilibrium of processes of excitation and inhibition. Therefore, when performing work in electric fields the action of strong discharges on persons must necessarily be avoided.

RULES AND REGULATIONS ON LABOR PROTECTION AT 400, 500, AND 750 kV AC SUBSTATIONS AND OVERHEAD LINES OF INDUSTRIAL FREQUENCY (IN THE USSR)

1. Extent and Order of Application of Rules and Regulations for Labor Protection for Work at Substations and on Open Transmission Lines With Voltages of 400, 500, and 750 kV ac of Commercial Frequency.¹

1. These rules and regulations are disseminated to personnel: A) serving active 400, 500, and 750 kV substations and transmission lines; B) serving working electric systems of any voltage (open and cable transmission lines and also lines of communication and so forth), located within the zone of influence in 400, 500, and 750 kV open transmission lines; C) carrying out construction, maintenance, and repair work on active 400, 500, and 750 kV substations and in the zone of influence of open transmission lines of the same potential (including consulting personnel).

2. These rules and regulations are required for the personnel for whom they are promulgated. Deviations from them are not permitted. Every worker if he cannot take measures to avoid infraction of standards and rules must immediately report directly to the director and in those cases of his absence to a superior, all infractions of standards and rules noted by him and also of any improper protective measures.

The administrative technical manager of an installation for personnel for which these rules and regulations are set forth may, depending upon local conditions, set forth additional measures increasing work safety. These measures must not contradict demands of these standards and rules.

3. Changes and additions in the rules in conformity with safety practice must be introduced in accordance with the requirements of these rules and regulations.

4. Responsibility for observation of these rules and regulations lies with the manager of the installation carrying out work on active substations and transmission lines of 400, 500, and 750 kV and in the zone of influence of open transmission lines of the indicated voltage.

II. Hygienic Standards

5. The electric field of 400, 500, and 750 kV substations and open transmission lines has an unfavorable effect on the human organism. Besides this at the moment a person touches metallic parts of equipment, construction machines, vehicles, and so forth, electrical discharges occur. The unfavorable influence of electrical fields and discharges on the human organism appears only in the zone of influence—the space in which the intensity of the electrical field exceeds 5 kV/m.

The degree of effect of the electric field on the human organism depends both on the intensity of the field and the length of time in it. The influence of electrical discharges on the human arising in the zone of influence is not permissible regardless of the time of its action.

6. The permissible duration that a person may be in an electric field of various intensities in the course of a day without protective means is given in the table. (See Table 6)

¹For further simplicity "substations and open transmission lines with a voltage of 400, 500, and 750 kV ac of commercial frequency" will be called 400, 500, and 750 kV substations and transmission lines.

TABLE 6

Numbers	Electric Field Intensity kV/m	Permissible Duration of Personnel Stay in Electric Field During 24 Hours (minutes)	Notes
1	5	unlimited	Points 2, 3, 4, and 5 of the regulations are valid if: 1) all the remaining time a man is in areas where electric field intensity is less than or equal to 5 kV/m 2) a possibility of electrical discharge influence is eliminated.
2	10	180	
3	15	90	
4	20	10	
5	25	5	

7. If the intensity of the electric field at the working site is not equal to the standard values, the permissible duration that a person may be in the electric field must be determined according to the next greater value of intensity according to the table of paragraph 6 of these rules and regulations. Interpolations in the table are not permitted.

8. Any work may be carried out in places in which the intensity of the electric field is equal to or less than 5 kV/m without restrictions of it by character or duration. If the intensity of the electric field at the work site exceeds 24 kV/m and also if duration of work safety conditions do not correspond to the demands of paragraph 6 of the present standards and rules the work must be carried out with the use of protective means.

9. In substations and open air lines the boundary of the zone of the influence of the electric field is located at the following distances from the nearest current carrying parts (in air): in 400 and 500 kV substations and open air transmission lines—20 meters; in 750 kV substations and open transmission lines—30 meters.

10. The boundary and the zone of influence on the magnitude of the intensity of the electric field at the work site may be made more precise when established as a result of measurements of the actual value of the intensity of the electric field. The intensity of the electric field is measured: A) at a height of 1.8 meters if the person is located on the ground; B) over the whole height of the man if the person is located on a device or on construction. The greatest measured value of intensity is the determining value.

III. Protective Measures and Their Basic Requirements

11. Protective measures must be applied in the zone of influence of electric fields while carrying out all forms of work if the duration is longer or the safety conditions for accomplishing the work do not correspond to the requirements laid down in the table of paragraph 6.

12. The following screening measures may be applied for the protection of personnel from the influence of electric fields: A) stationary shielding of the structure, B) portable shielding structures, and C) individual shielding outfits (shielded clothes).

13. Stationary and portable screening structures must be grounded and must insure reduction of the intensity of the electric field at the work site to a magnitude of 5 kV/m or less.

14. Stationary shields may be made in the form of baffles, curtains, or partitions. Baffles are made of metallic mesh. They are placed over work sites at unit cabinets and air breaker control compartments, at terminal blocks and conductors of disconnect (if these leads jut out from behind the structures from which the disconnect stands), at 380V units, power distribution bays, and at filters of connections and other devices and equipment requiring periodic service.

Curtains are made of steel cable conductors, reinforcement, and so forth. They are set up over walkways and over other sites of distribution equipment from which inspection of equipment may be carried out.

Partitions are made of metal conductors. They are set up vertically between two neighboring bays. Grounding of stationary shielding devices must be accomplished by connecting them to the network ground or to a grounded object (by welding or by bolting).

15. Portable shields may be made in the form of stock curtains, tents, dividers, panel, and so forth. They are placed over work sites and also between live cubicles and dead cubicles or cubicles under construction. Portable panels are expedient to use as removable lateral screens in scaffolding used when working on circuit breakers, in bucket lifts, and so forth. Grounding of portable screens must be carried out by connecting them to the network ground or to a grounded object for which they must have special ground leads and clamps.

16. Personnel or individual shielding devices are used in the absence of stationary and portable shields. The use of personnel devices are prohibited in those cases where contact with current carrying energized parts is possible, in particular when working on panels, electric leads, installations, and circuits up to 1000 volts, during preventative inspection of equipment (for those persons directly carrying out the task) and while arc-welding. Protection of personnel in these cases must be carried out with stationary or portable shielding.

17. The protective properties of the personnel shields are insured by construction and observation of the rules of their use. Individual shielding devices consist of the following elements: A) protective suit-jacket and pants (or coveralls), B) shielded head covering-metallic or metallized plastic helmet for warm seasons or a fur cap with ear pieces covered with a covering of metallized cloth for the cold seasons, C) special shoes having conductive rubber soles or made wholly of conductive rubber (shoes, boots, galoshes with felt linings).

Special shoes are the principle means of grounding of individual shielding assemblies. All elements of a personnel shielding device for protection from the action of electric fields must be used together and must be reliably electrically connected with each other with conductive jumpers.

18. For tasks connected with contact to ground objects, personnel shielding devices must be further grounded in the following cases: A) when the person is on ground with low conductivity (concrete, gravel, wooden flooring, etc.), B) when the person is located on grounded construction but the as-

sembly is isolated from "ground".

Platforms of fluted metallic sheets or screen on which the person must be doing the work may be used for additional grounding. Platforms must be grounded. They must be provided with special clamps and cables for grounding. Additional grounding of the assembly may be accomplished also by way of grounding of special leads and joining it to any of the conductors connected with the assembly.

In all other work, in particular in work not connected with a person's touching grounded objects or if he is located directly on metallic grounded construction on damp sand, earth, or grass, additional grounding of the personnel shielding device is not required.

19. When working in the zone of influence of the electric field vehicles and mechanized devices on rubber tracks or tires must be grounded. Grounding must be accomplished by conductors. Bodies or frames of machines and devices must be equipped with special clamps for grounding. Besides this, these machines and devices must have metallic chains which must be connected with the frame or the body. Before entering a substation or the zone of influence of a transmission line the chain must be let down and be in contact with the ground.

20. Vehicles and mechanized devices (mobile laboratories and workshops, cranes, tractors, etc.) the roofs and bodies of which are metallic and reliably grounded are comparable to a shielding structure.

21. Devices and equipment which during work in the zone of influence of an electric field may be isolated from ground (blocks on an insulated rope, unrolled conductors, etc.), must be grounded.

IV. Special Work Procedures in 400, 500, and 750 kV Substations

22. All work in the zone of influence of an electric field without being up on a device or construction (that is on the ground), must be carried out with the use of shielding if the standards given in Table 6 cannot be insured.

Work carried out up on devices and construction must be carried out with the application of shielding independent of its duration. Exceptions include operational servicing of transformers and shunt reactors not requiring elevation to the input (oil sampling from it or from the input, servicing the cooling system, control and measurement devices, light repair, etc.). This work may be carried out without shielding independent of duration in view of the adequate shielding provided by the cases of the transformers and shunt reactors.

23. Work in production in ancillary compartments, at control desks, in transformer vaults, in compressor, shop, and other facilities made of reinforced concrete may be carried out without protective measures independent of the distance between the compartment and the current carrying parts under voltage.

24. Partitions (stationary and temporary) eliminate the influence of an electric field only of neighboring connections. The influence of an electric field of a given connection or bus located overhead for work without removal of voltage is eliminated by other means of shielding.

25. Before carrying out work, however short, it is necessary to ground all current carrying parts isolated from

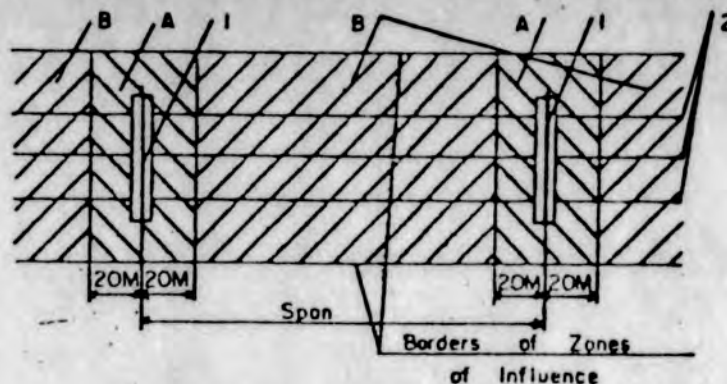


Figure 1. Diagram of 400 and 500 kV transmission lines with zones of influence.

- 1 Tower (intermediary, anchor, or corner).
- 2 Transmission line conductors.
- A Zones in which work is permissible without the use of protective measures and without time limitation (distances are given in the diagram).
- B Zones in which work is permissible without protective measures for durations of no more than 90 minutes.

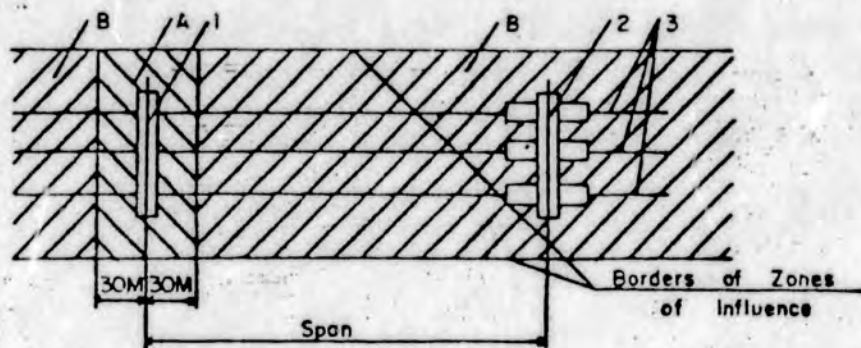


Figure 2. Diagram of 750 kV transmission lines with zones of influence.

- 1 Intermediary tower.
- 2 Anchor or corner tower.
- 3 Conductors.
- A Zones in which work is permissible without protective measures for duration of no more than 180 minutes (distances given in the diagram).
- B Zones in which work is permissible without protective measures for durations of no more than 10 minutes.

ground and to disconnect portions of the bus which it is possible for the worker to touch. Disconnected current carrying parts of nearby devices must also be grounded even in those cases where work on them is not anticipated. Grounding must be accomplished with a grounding blade or portable grounding.

V. Special Work Procedures in the Zone of Influence of 400, 500, and 750 kV Transmission Lines.

26. Work carried out on the ground in the zone of influence of 400 and 500 kV transmission lines without protective measures is permitted (see Figure 1): 1.) at a distance up to 20 meters (along the ground) from the axis of the tower independent of the type of tower, without limitation of time; 2.) in the span of the transmission line for no more than 90 minutes. Measures must be taken to exclude the possibility of the action of electric discharges to the person.

27. Work carried out on the ground in the zone of influence of a 750 kV transmission line without the use of protective measures is permitted (see Figure 2): 1.) at a dis-

tance of up to 30 meters (along the ground) from the axis of intermediary towers for no more than 180 minutes; 2.) in the span of the transmission line and close to anchor and corner towers for no more than 10 minutes. While working both close to towers (intermediary, anchor, or corner) and on other portions of transmission lines measures excluding the possibility of electrical discharges to the person must be taken.

28. If the duration of work on the ground in the zone of influence of 400, 500 and 750 kV transmission lines exceeds the time given in paragraph 26 and 27, or if the work is off the ground at height (up on the tower or in a bucket lift or other lifting device) it must be carried out using protective measures.

VI. Medical Examinations and Contra-Indications

29. Personnel subject to these rules and regulations (see para. 1) must pass preemployment and periodic medical examinations in correspondence with the order of the Minister of Health (USSR) of May 30, 1969, #400, "Preemployment and Periodic Medical Examination of Laborers".

APPENDIX I

Discussion of Paper 23.06 at CIGRE 1972

CIGRE Proceedings, Vol. 1, Group 23, pp. 24-29

Mr. V. V. BOURGSDORF (U.S.S.R.)—The problem of the effect of very high voltage electric fields on staff has become very important since the first 500 kV substations have been made live. The gradients are fairly high, about 10, 15 and even more than 20 kV/m.

This problem is also topical in the case of a number of test installations.

Research which has been carried out has been published in the Paper and it is possible to provide special solutions with a fairly high degree of safety.

Measures for protecting staff in substations have been successful and we have no longer complaints and no longer undesirable cases.

These recommendations have been introduced into the official safety regulations for service staff and have been drawn up and published in the specifications for the 500 and 700 kV substation projects.

Mr. L. CAHILL (Canada)—Staff who carry out maintenance work in the 735 kV substations of Hydro-Quebec do not appear to have been subjected to any serious trouble caused by the electric field.

In 735 kV substations the lower busbars are 10.7 m from the ground and the upper busbars about 13.7 m higher. The adjacent phases of the various bays are different colours.

Originally the staff complained of annoying discharges when they carried out maintenance work on the equipment. This problem has been solved by attaching metal working platform rigidly to the equipment and by checking the resistance of the soles of the shoes.

Furthermore, the staff has not complained of any physical or chronic mental suffering which seems to have been caused by the effect of the electric field. There is no screen above the pathways or the control cubicles in the 735 kV substations.

Experience concerning the effect of the electric field under 735 kV transmission lines is excellent. The conductors are a minimum of 14 m above the ground. The enclosures of metal grids supported by wood poles along the line have been earthed. The linemen working at live line maintenance of 735 kV lines by the bare hand method wear over-garments which form a Faraday cage and shoes with conductive soles. They have made no complaints concerning their health.

Paper 23-06 gives rise to certain misgivings and we have the intention of carrying out additional tests so that we can make sure that our staff work in complete safety.

We will be happy to exchange information with our Russian and Japanese colleagues who have also worked on this problem.

Study Committee 23 should form a Working Group in order to define and standardise the terms, methods of measurement and methods of analysing the results. This work should be carried out with a certain amount of discretion so that the population does not fear more than it ought the

pollution of the environment by electric fields.

Before concluding, I would like to ask the authors of Paper 23-06 if the physiological effects observed on staff in 500 kV substations are irreversible? Are these effects caused solely by the presence of the electric field without any sudden discharge by contact between the staff and the equipment under maintenance?

The CHAIRMAN—Thank you very much, Mr. Cahill, for that contribution and especially the proposal for further studies in this field before any panic occurs. This is very important, and I am sure my colleagues in the Study Committee will agree to take up this problem.

Mr. H. SINGER (Germany)—I should like to make a few remarks on Question 2.1: What observations have been made in other countries?

It might be of interest for the audience to hear, that at the Institut für Hochspannungs und Anlagentechnik, Technical University Munich, in cooperation with the Forschungsstelle für Elektropathologie, Freiburg, investigations were started about one year ago with a view to get information on the influence of 50 cycle electric fields on the human body. In this endeavour the calculated electric field underneath overhead transmission lines up to 1100 kV of the order of around 10 kV/m has been simulated in a climate laboratory, where the test persons had to undergo a cycle of 45 min at zero field, 45 min at 15 kV/m and finally 45 min at zero field.

In the course of a first series of tests the electrocardiogram, the electroencephalogram, the blood pressure and the pulse have been measured and in a second series the reaction time was investigated. In the first test row no significant influence could be found up to now by the presently used method of evaluation. However, as can be seen from Figure 30, a significant influence at the reaction time tests, carried out with ten test persons, could be derived: after a zero field period the reaction time increased during the 15 kV/m field period and decreased again during the following zero field period. Additionally, it may be pointed out, that even in a 1 kV/m electric field an increase of the reaction time could be stated.

These preliminary tests are evidently demonstrating the necessity of further tests with a greater number of persons with the main aim to find the threshold value of the electric field strength, where no influence on the human body can be expected.

The CHAIRMAN—Thank you, Dr. Singer. It would be very interesting for us to hear in the future of the very detailed studies in this field. I am very glad to hear that they are continuing.

Mr. A. C. FAGERLUND (United States)—We were quite interested to read of the difficulties the authors have en-

countered with electric fields in EHV substations at 500 kV and above. There are many 500 kV substations in service in the U. S. which have been energised for a number of years. No special shielding equipment for personnel is utilised at this level, yet, no complaints by substation personnel have been made.

Since the distances between buses and equipment are important, we wonder whether substations in which problems have been experienced are substantially more compact than most U. S. designs. These designs inherently provide for greater distances between buses and equipment or other buses. The closest energised bus parallel to a substation crew providing circuit-breaker maintenance is approximately 23 m from the nearest phase of the bus to the circuit-breaker center. This is in excess of the 20 m recommended in the paper and hence may clarify the difference between our experience and that of the authors.

We understand that shielding similar to the type described in the paper is provided in some U. S. 765 kV substations to shield personnel while operating disconnection switches. However, to our knowledge, no shielding is provided during maintenance operations.

We strongly feel that the study of the detrimental effects of electrical fields on personnel working in EHV and UHV environments, should be pursued further, and they are being pursued vigorously in the U. S. A. We regret that the references which the authors have mentioned are not more easily obtained, as we would like to review these in detail.

Mr. T. FUKUNISHI (Japan)—I should like to comment on Question 2.1, because this problem is very important for us.

As regards the first part of the question, we can state that in the 500 kV substations now under construction in Japan the electric field strength at the height of 1 m above the ground is designed to be equal to, or below, the strength at the 275 kV substations in which we have had experience over 10 years and which have not caused any big trouble.

I turn to the second part of the question. Especially at seaside districts, the protection design against salt pollution is considered to be the insulation of equipment. Therefore, the height of the live part of equipment is so great that we do not study marginal conditions.

On the third part, we have no example to be expressed, but, due to the report above mentioned it is recognised that the conductive shoes and overalls are effective to protect the personnel against electrical fields.

Fourthly, we consider that a metal-clad installation sufficiently protects personnel against electrical fields.

Mr. J. BUTER (Germany)—In the conclusions of Paper 23.06, the authors pointed out that for an electrical field on the ground equal to 5 kV/m or lower there is no influence on man. Because of our long-term experience in Germany, I think it is very important to underline this result.

Practically, this limit of 5 kV/m means that no influence on man occurs in switchyards or on lines operating with a voltage of 300 kV or lower. In our 380 and 220 kV switchyards, field

strengths of this value or only a little higher have been found. The values under lines are even lower.

We have been operating 220 kV networks for 43 years and 380 kV networks for 15 years. In all this time, no event with an unfavourable effect on the human organism has been known. However, at higher voltages it is advisable to carry out accurate studies of the problem. To make the result of such studies comparable, it would be interesting to get more details from the authors of Paper 23-06 about the measuring procedure and devices concerning both the field strengths and the effects on human beings.

Mr. V. CALECA (United States)—I am presenting this discussion also in the names of Messrs. Kolcio and Shih, of the American Electric Power Service Corporation, colleagues of mine.

We are happy to take this opportunity to discuss the paper presented by Madame Korobkova and her associates, and in particular to reply to the question posed by the Special Reporter: What observations have been made in other countries regarding the electric field effect on the human body?

The American Electric Power Company has conducted a study oriented towards the influence of the electric field on men involved in maintenance work on energised EHV lines. In addition to medical investigations, an experimental study has been conducted by exposing mice to strong electric fields. These investigations were conducted by the medical group of the Johns Hopkins University under the guidance of D. W. B. Kouwenhoven. In 1966 five IEEE papers were written on the evaluation of physical and medical effects of AC electric fields encountered in energised line work. One paper gave a four-year medical evaluation of men working in electric fields, and this is covered in [1]. A second paper [2] covered the exposure of mice to an electric field of up to 160 kV/m and concluded that there was no detrimental effect.

Our linemen working on lines energised at 345 kV use two distinct methods, the "barehand" method and the "hot-stick" method. Most of the "barehand" work is performed from a basket supported by the insulating arm of an aerial lift truck. In such cases the basket is provided with a conductive shield on all four sides which is only waist high and on the bottom, and this shield is bonded to the energised conductor. Other "barehand" techniques used included working from insulating platforms or ladders. In the latter cases the linemen wore conductive clothing consisting of a suit with a hood, gloves and footwear. Where "hot-stick" work was performed no shielding was used but the linemen were separated from the energised conductors by the length of the stick, which is 3 m for 345 kV.

Under all of these circumstances it is reasonable to assume that the linemen were immersed in an otherwise uniform field, whose magnitude depended upon the average distance between the lineman's body and the energised lines. At 345 kV, for instance, these background field strengths vary typically from 15 kV/m to 100 kV/m at 3 m and 0.5 m from the conductors respectively. In all cases the electric field is intensified by the presence of the lineman's body, which can be considered

essentially as a perfectly conductive medium. The intensification factor, according to an analytic calculation [3] can be as high as 50 times at the body extremities closest to the conductors.

Test results [1 and 4] at 345 kV obtained during barehand work using a basket in which the man was shielded up to the waist gave a maximum body current of 660 mA at a maximum intensified fieldstrength of 470 kV/m at the top of his head. During hot-stick work the maximum body current was about 400 μ A while the maximum intensified fieldstrength was in the neighbourhood of 200 kV/m at the knee exposed to the conductors.

At 765 kV, electric field effects such as hair-nerve stimulation, tingling between body and clothes and discomfort due to arc discharges naturally could be more intense than those observed at 345 kV. To provide comfort for linemen doing barehand work, more complete shielding is used. It is our experience that conductive clothing effectively shields the linemen from the electric field. At 765 kV the body current is reduced to an insignificant level. For example, for a lineman wearing conductive clothing, and bonded to a 765 kV conductor, with his face exposed to the electric field, the measured body current was only about 40 μ A.

We have received no complaints of deleterious health effects from electric fields while operating 345 kV lines and stations for 20 years and 765 kV lines and stations for over three years.

Finally, the following comments pertain to the use of screens and conductive clothing. We find no protection is necessary for personnel doing maintenance, inspection or any other routine work at ground level. Therefore no screens are installed in our stations. Contrary to the authors' report, the type of the conductive clothing used by our linemen is comfortable for use in both hot and cold weather.

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- [3] H. C. Barnes, A. J. McElroy, and J. H. Charkow—Rational analysis of electric fields in live line working. (ibid)
- [4] C. J. Miller—The measurement of electric fields in live line working. (ibid)

The CHAIRMAN—I have pleasure in welcoming to the rostrum Mr. Barnes, the Chairman of Group 31.

Mr. H. C. BARNES (United States)—This supplements the comments of Mr. Caleca.

The authors of Paper 23-06 indicate that men working in high voltage substations are disturbed by the fields in these stations. This is contrary to the findings of the American Electric Power Corporation. Men working on the ground

experience no discomfort even though no shielding is provided. This is the result of design which keeps voltage gradients within proper limits. Even a station of lower voltage can have discomforting levels if not properly designed.

For 765 kV our minimum bus clearance to earth is about 13 m and about 7 m is maintained from the bottom of insulating supports and bushings. Shielding is provided when working near energised buses, as described by Mr. Caleca.

The authors' indication of medical and psychological disturbances is contrary to the findings of extensive pathological and neurological research carried out for us by the staff of Johns Hopkins Hospital. The comments of Dr. Ing, W. B. Kouwenhoven and Dr. Martin L. Singewald, medical doctor of Johns Hopkins, from which I will quote later, are appended to this discussion.

Dr. Kouwenhoven is America's foremost authority on electrical safety; although an electrical engineer, he has long been a lecturer in heart surgery and is the inventor of the defibrillator: included in his many honours is an honorary degree of doctor of medicine. Dr. Singewald is a noted medical doctor who also holds a degree in electrical engineering taken under Dr. Kouwenhoven.

They and several members of the Johns Hopkins staff have carried out a nine-year programme of research which included measurements and medical observations of the men while they themselves, as well as the men, were energised at full line voltage of up to 780 kV using the barehand maintenance technique.

I now quote their statements:

"The authors have presented an excellent paper on the results of their investigation on the effect of 500 and 750 kV electrical fields in switchyards. The paper states that switchyard or substation workers are affected by these electrical fields. Most of these effects which are reported are subjective. The authors also state that medical and physiological studies were made. However, we found no supporting evidence for these results.

In the United States we have been conducting research for nine years on 10 linemen working on energised high voltage lines. Half of the men worked from screened insulated box baskets while connected directly to the line and the other half worked with hot sticks while standing on the steel towers. Each man spent about 100 hours a year on high voltage lines with potentials of 345 to 765 kV. Average field strengths were 11-12 kV per inch, as contrasted to the 5 kV/m mentioned as a limit in Paper 23-06.

During the nine years, each man was subjected to seven complete medical histories and physical examinations. Each examination required a stay at the Johns Hopkins Hospital of three and a half days. The history and physical examinations were performed by members of the hospital staff and included a complete laboratory survey of each man. The medical survey consisted of consultations with an ophthalmologist, an otolaryngologist, a urologist and a neuro-psychiatrist. The laboratory survey consisted of complete hematological studies and blood chemical studies, which included serum urea nitrogen, blood sugar and serum cholesterol, uric acid, urine

analysis and stool examination. In addition, thyroid, kidney and liver functions were evaluated. Electrocardiograms and electroencephalograms were recorded, and hearing was tested. X-rays of the chest and hands were obtained at each of the examinations as well.

It can be reported that the health of each one of these 10 men has not changed in any way from their exposure to the high voltage lines within the limit of these studies. There was one child born during the nine years of the survey.

No abnormalities were found which could be ascribed to the exposure to electrical fields. All of the men were in first

class physical and mental condition when examined in January and February of 1972. No X-ray radiation was found, nor the effects of working barehanded on energised line conductors. There were no complaints of nuisance discharges, headaches or other subjective ills.

Therefore, we cannot agree with the statement in Paper 23-06 that 5 kV/m is the maximum voltage a normal man can stand.

The results of this completed study will be presented at the 1973 Winter meeting in New York of the IEEE Power Engineering Society."

G. G. Knickerbocker

Three other articles published in the Soviet literature and dealing with the exposure of man and experimental animals to commercial power frequency electric fields have been translated. However, the quality of illustrations in the originals does not make it possible to satisfactorily reproduce these papers at this time. They are abstracted below.

THE PHYSIOLOGICAL INVESTIGATION OF THE EFFECTS OF A HIGH TENSION, INDUSTRIAL FREQUENCY ELECTRICAL FIELD ON LIVING ORGANISMS

T. I. Belyaeva and K. V. Stroikova

Based on observations reported by Stroikova (1952) people complained of various sensations while working near or on high voltage transmission lines—up to 220 kV—laboratory investigations of the exposure of both experimental animals and human beings to high intensity electric fields were carried out and reported in this paper.

In the animal studies 345 mice and 12 rabbits were used, of which some of each served as unexposed controls. The animals were exposed either to 65 or to 130 kV repeatedly with single exposures as long as three hours. No values of electric field intensity were cited. Electric field effects upon mortality and weight change were studied in the mice; temperature, thermoregulation and blood pressure in rabbits.

No direct effect upon mortality of mice was noted though the authors report metabolic disorders, lowered resistance to infection, paralysis, necrosis and late deaths from secondary causes which did not occur in control animals. In rabbits, the authors believe that compensatory mechanisms of thermoregulation are affected by exposure. Blood pressure in rabbits tended to be higher during exposure but was within normal limits.

Human subjects underwent testing to determine the effects of exposure to a conductor, two meters distant and energized with 65,000 volts. Fifteen to twenty exposures each lasted from 0.5 to 3 hours. Three groups of three people each were studied. Thermoregulation as determined from rectal temperature, cardiovascular reflexes measured by a plethysmographic technique and performance tasks (manual and verbal) were tested.

The authors contend that their studies show demonstrable changes in the human subjects as a result of the series of exposures. Among them are: slight lowering of body temperature modification of thermoregulator mechanisms, altered vascular regulatory mechanisms and lowered work efficiency.

THE INFLUENCE OF AN ELECTRIC FIELD OF COMMERCIAL FREQUENCY AND DISCHARGES ON THE HUMAN ORGANISM

T. I. Krivova, V. V. Lukovkin, T. E. Sazanova

This article first describes briefly the findings of examina-

tions carried out on 319 men during and after work on 220, 330 and 500 kV switchyards. The authors report that the electric field evoked an unfavorable influence causing non-specific disturbances of the functional state of the central nervous system (CNS) and cardiovascular system, and hematologic changes. Specifically, they cite autonomic system dysfunction, variability in arterial pressure and pulse rate, reticulocytosis and qualitative changes of neutrophils.

A number of different experimental studies were briefly described and the results summarized. Twenty three young men participated in various experiments which included (a) exposure to field strengths ranging from 10 to 32 kV per meter, (b) being subjected to a body current equivalent to the displacement current resulting from an electric field, (c) the occurrence of capacitive discharges from the body while in the field.

No results are reported pertaining to study (a). The authors claim that the results of (b) suggests that displacement current alone is not sufficient to explain all the phenomena attributed to exposure to an electric field.

Most of the discussion of results pertain to the third experimental study—capacitive discharges. Changes in pulse and respiratory rate and electrocardiographic R-S wave amplitude were studied. An effect of sub-pain threshold stimuli upon autonomic function was notable among their reported findings. Adaptation to pain was observed and was, as might be expected, more marked with regularly occurring discharges than with random.

STANDARDIZATION OF THE INTENSITY OF AN ELECTRIC FIELD OF COMMERCIAL FREQUENCY BY THE THRESHOLD OF PAINFUL STIMULATION OF ELECTRICAL DISCHARGES.

T. I. Krivova, S. A. Lebedev, Yu. A. Morozov,
M. D. Stolyarov, V. I. Filippov

Assuming typical values for the capacitive coupling of a person both to an overhead transmission line and to ground, the authors calculate the discharge currents which can occur when a person touches a grounded object while in the field of an energized transmission line. Drawing upon well known published data they show that the calculated energy released in such discharges (1.6×10^{-2} watt-seconds for a 300 kV system) is well below that normally considered life-threatening.

They then describe an experimental study to determine the electric field strength necessary to cause discharges to an ungrounded object at the pain threshold of human subjects. The subject stands on a 3 mm thick sheet which insulates him from a grounded plate 1.5 X 1.5 meters. A similar plate 4 meters above the surface on which the subject stands is energized and the voltage adjusted until the discharges evoked between the subject index finger and a grounded object are on

the verge of producing pain. The subject then steps out of the test array and the electric field at the level of his head is measured. The authors present a statistical analysis of the

threshold determination in 30 subjects which shows that at 5.18 kV per meter, 80% of people will not experience painful sensation upon discharge.

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APPENDIX IV ACKNOWLEDGMENT

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#2

EPRI'S RESEARCH PROGRAM ON BIOLOGICAL EFFECTS OF ELECTRIC FIELDS

HARRY A. KORNBERG

EPRI'S RESEARCH PROGRAM ON
BIOLOGICAL EFFECTS OF ELECTRIC FIELDS^{1/}

Harry A. Kornberg^{2/}

Abstract.--Since available technology and capital make necessary overhead transmission lines at least to the year 2000, Electric Power Research Institute is sponsoring environmental research on effects of mechanical, chemical, and physical factors associated with the transmission of electricity. Only EPRI's research on biological effects of the physical factor is reviewed here. Human exposure to natural and man-made magnetic and electric fields are common and are associated with electric storms and ordinary electric equipment, such as hairdryers and soldering irons. Nonetheless, reports of illness among some Russian switchyard workers, and conflicting reports of biological effects under controlled laboratory conditions, stimulated expansion of research projects in this area supported by EPRI. These are summarized in this paper.

INTRODUCTION

The nation's electric utilities currently operate approximately 500,000 circuit miles of overhead electric line rated 22 kV and above. This includes 90,000 circuit miles of transmission line rated 230 kV and higher. Transmission voltage over the years has gradually increased to its present nominal operating maximum of 765 kV. The reason for the increase is that, as line loading (current) increases, line losses also increase. Increasing the voltage permits the transfer of larger amounts of power, minimizes losses and allows more efficient use of scarce rights-of-way. The Federal Power Commission (1971) has estimated that there will be 118,500 miles of 230 kV and above transmission lines in service by 1980, and 159,200 miles by 1990. However, the largest percent increase was forecast to occur at 500 kV and higher. The 14,000 (approximate) circuit miles now in service was predicted to increase to 24,000 circuit miles by 1980 and to 42,000 circuit miles by 1990. Without the use of HV

overhead transmission, the nation's utilities would be unable to serve the large and concentrated urban loads from power stations located far from the load centers at a reasonable cost for electricity.

High capacity underground transmission via superconducting cables may be a reality in the late 1980s; but, as of now, this technology is still in its infancy, and much additional research is required to improve both conducting and insulating materials. The remaining alternative to HV overhead transmission is underground cable, using technology that is already available. However, the cost of equivalent underground transmission is estimated to be 12 to 16 times higher than overhead construction (Salvage 1975). If all future transmission lines were to be underground, costs of electricity would increase 30 to 50%. If, additionally, existing lines were also to go underground, costs of electricity would at least double (Schulte 1975).

Assuming that overhead transmission lines will be with us to the end of the century, it is necessary that their environmental impact be understood and minimized whenever possible. The three agents responsible for environmental impact are: mechanical--clearance, construction, and maintenance of ROWs; chemical--principally herbicides; and physical--electric fields.

^{1/}Paper presented at the Environmental Concerns in Right-of-Way Management Symposium, Mississippi State, Miss. January 6-8, 1976.

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For more than a year, Electric Power Research Institute had been expanding its research in these areas.

EPRI began to function in September of 1973 with a staff of 12 people. By June 1974 the staff totalled about 200, and a significant increase in numbers of EPRI-sponsored research projects was initiated. One area that appeared unusually clouded with opposing issues, was that of the biological effects of electric fields. Our response was to select a research contractor experienced in electric field effects, and request a comprehensive state-of-the-art review to identify what is known and what is not known in order to formulate a research plan for the future. The contractor, IIT Research Institute, completed its task in December 1975 when the final report to RP381 became available (EPRI 1975). From this nearly-exhaustive review, several interesting conclusions were drawn.

The maximum vertical field under a typical 765 kV line at four feet above the ground is about 9 kV/m. (The corresponding magnetic field generated by 2000 A current flow is 0.31 Gauss.)

Gradients from powerlines may be compared with natural and other man-made electrical fields. Beneath thunderclouds, 3 kV/m and more have been measured. Dust storms in northern West Africa can reverse the earth's 0.13 kV/m field (caused by the ionosphere) and produce fields up to 1.5 kV/m. The earth's natural magnetic field is about 0.5 Gauss.

Examples of man-made ac electric fields appear in Table 1. Some sources of man-made magnetic fields are soldering guns and hair-driers which can generate 10-24 Gauss in their vicinity, and a can-opener, kitchen range, and electric shaver which can generate 5-10 Gauss (EPRI 1975). Thus, exposure of mankind to natural electric and magnetic fields occurred before electricity was harnessed, and to man-made fields before high voltage transmission lines were constructed.

Reports from the U.S.S.R. (Korobkova et al, 1972; Lyskov et al, 1975; Krivora et al, 1975) stated that occupationally-exposed linemen experienced nausea, lassitude, loss of appetite, and reduced sexual drive. Subsequently, the U.S.S.R. promulgated time limits for exposure to electric fields greater than 5 kV/m. A report from Spain described a similar syndrome among switchyard workers transferred to a new 500 kV station. These reports stimulated an intensified interest as to whether higher voltage gradients under some transmission lines and in switchyards can cause biological effects.

Table 1.--60 Hz Electric Fields in the Vicinity of Electrical Appliances (measurements were made 30 cm from appliances).

Appliance	Electric Field (volt/meter)
Electric Blanket	250
Broiler	130
Stereo	90
Iron	60
Refrigerator	60
Hand Mixer	50
Toaster	40
Vaporizer	40
Phonograph	40
Color TV	30
Coffee Pot	30
Vacuum Cleaner	16
Clock	15
Electric Range	4
Incandescent Light Bulb	2

Investigations in other Western European countries and in the U.S. have produced different findings. Table 2 summarizes tests using human subjects (EPRI 1975). Inability to confirm the Russian and Spanish observations suggests that the effects noted may have been caused at least partly by factors other than the electric field which are not common to all working conditions.

A similar situation exists for experimental work using laboratory and agricultural animals. Such research is summarized in Table 3. Male progeny of mice exposed to 160 kV/m for 1500 hours in the experiment reported by Knickerbocker, et al. (1967) showed a slightly decreased growth rate compared to controls. However, the authors pointed out that the controls had free access to water which was denied the exposed group when the field was on. They also added that the exposed group was located nearer a window than were the controls, which could have allowed greater body heat loss among the exposed group.

It seems that wherever positive results are noted, they can be ascribed to factors other than the electric field. That offspring of exposed animals showed decreased growth rate could have been due to differences in water availability and temperature. That research on human subjects in Western Europe and the U. S. cannot reproduce the syndrome reported by the U.S.S.R. suggests that factors other than the electric field may be responsible. Candidates include noise (100 Hz transformer

Table 2.--Summary of American and Western European Tests Using Human Subjects.

Subject (Investigator)	Frequency	Stress	Indicator	Results
Humans (Koeppen)	50 Hz	7.5/2.5/27 kV 30 minutes	EKG	No effects
525 Humans and controls (Strumza)	50 Hz	Long duration fields within 25 m of 200/400 kV line vs fields beyond 125 m for controls	Visits to and by physicians use of medi- cine, medical histories	No significant difference observed in subject and control groups
10 Males 10 Females	50 Hz	100 kV/m	Psychologi- cal test subjective responses	No statistical difference was observed in test perform- ance, some dis- comfort report- ed by a few subjects also influenced by weather
Farm workers and livestock 18 farms (Busby)	60 Hz	Fields from 765 kV line	Questionnaire response	No significant effect attribu- ted to fields from lines
Human 11 American Linemen (Kouwenhoven)	60 Hz	Fields en- countered in normal line and bare-hand work	Physical examination CV, ECG, kidney, visual, auditory, emotional status	No effects
10 Humans (R. Hauf)	50 Hz	1, 15 kV/m intermittent 45 minute exposure	ECG, EEG, pulse, blood pressure reaction time	No significant changes except for small decreases in reaction time
6 Humans (3 Male) (G. Hauf)	50 Hz	1/15/20 kV/m Alternating 45 minute exposure	EKG, EEG, Blood pressure reaction time	No Pathological changes

noise), noxious vapor from paint, chemicals or switchyard equipment, and diseases possibly endemic to the region.

More precise resolution should come from a systematic search among the candidate fact-

ors and from additional field and laboratory research. In order to identify a set of priorities for such further research, on the biological effects of electric fields, a workshop comprised of qualified consultants was organized by IITRI while under contract

Table 3.--American and Western Europe Tests Using Agricultural and Laboratory Animals

Subject (Investigator)	Frequency	Stress	Indicator	Results
22 Male mice (Knickerbocker, et al.)	60 Hz	160 kV/m 1500 hours	Weight gain physiological para- meters, necropsy	No differences between subjects and controls
Male guinea pigs, mice, rats (Meda)	50 Hz	100 kV/m 18 hrs/day	EEG, ECG, blood analysis	No chronic changes of sig- nificance/transitory changes EEG & ECG, some suggestion of infection-like responses
Rats (Strumza)	50 Hz	17 kV/m 4 to 23 months	Clinical and biological	No differences between subjects and controls
Mice (Moos)	60 Hz	1 kV/m	Lifetime of mice given lethal 900 rad x-ray	No significant effect attributed to electric field
Chickens (Krueger & Gariola)	60 Hz	3600 V/m	Weight gain	No statistically signifi- cant difference between subjects and controls
Rats (Spittka)	50 Hz	50 to 70 kV/m	Trained rats in Skinner Box reac- tion time	Inconclusive--reaction time altered, short and long- term effects suggested
Livestock (Ware)	60 Hz	Fields from 765 kV line	Survey 166 Farms 106 responses questionnaire	104 responses, no effect was noted, 1 suggested grazing pattern altered; 1 concerned loss of cow

to EPRI. The following recommendations were developed at this workshop. Of the 23 separate topics, 11 are or soon will be among EPRI's research projects.

RESEARCH PRIORITIES BIOLOGICAL EFFECTS OF ELECTRIC FIELDS

Existing Environments

Influences on Humans

Medical record comparison
Perception of fields and arc discharges

Effects on Animals

Agricultural animals
Insects
Birds

Plants and Ecosystem Considerations

Crops
Ecosystems

CONTROLLED SIMULATED ENVIRONMENTS

Psycho-Physiological Functions

Rodent
Pig
Nonhuman primate

Special Objective Tests

Small arc discharge effects -- pig
Seizure latency -- rodent/primate
Behavioral/physiological as appropriate--
human

Vegetation

Acute damage -- large plants and trees

MEDICAL DEVICES

Pacemakers
Long-term compatibility with existing
and future devices
Metallic implants

DOSIMETRY AND SUPPORT

Peer review and environment verification
Data bank and information exchange
Relating other biological data
Collateral environments
Exposure profiles
Laboratory instrumentation

To aid in the continuing process of developing research plans and priorities, and to review research progress, EPRI recently formed an Advisory Committee on Biological Effects of Electric Fields. It is comprised of about a dozen distinguished engineers and scientists, as well as representatives of government and industry.

The following list summarizes EPRI's eight research projects on biological effects of electric fields in progress at the time this paper was presented:

EPRI's RESEARCH PROJECTS ON BIOLOGICAL EFFECTS OF ELECTRIC FIELDS - JANUARY 1976

Number/ Contractor	Principal Experimental Observations
RP98 Johns Hopkins U.	Cardiovascular and other stress related response in individual nonhuman primates and dogs.
RP129 Westinghouse and Penn State U.	Leaf tip effects, egg hatchability, vole behavior and reproduction in simulated ecosystems.
RP381(a) ITT Research Institute	State-of-the-art review of biological effects of electric fields.
RP381(b) ITT Research Institute	Performance of special tasks on request: Aid other contractors in electrical engineering problems - electrode design, dosimetry, analysis of other research projects.
RP581 Battelle-Northwest	Behavioral, biochemical, hematological, and physiological response in Hanford Miniature Swine to be exposed in groups for prolonged periods. (See Text.)
RP679 ITT Research Institute	Effects on cardiac pacemakers implanted in non-human primates

TPS76
U. of Illinois

Effects on honeybee behavior and production under natural conditions.

TPS76
Equitable Environmental Health

Epidemiological study of health of linemen and switchyard workers. (Not on-going as of January, 1976, but feasibility study being planned.)

EPRI anticipates expenditures for research in this area between one to one and one-half million dollars annually. The project numbered RP581 is especially noteworthy, since guidance on parameters to be measured in the large animals will come, for the most part, from observations to be made on experimental mice and rats. The small animal portion of the experiment will be performed in parallel by the team of investigators and will be supported by ERDA, the Energy Research and Development Administration.

This is a major effort to seek a very subtle and elusive biological effect, assuming there is one caused by electric fields. Further, it is not the only effort being made in this direction. In the U.S., ERDA is supporting research on electric field effects on materials and genetic material. Elsewhere, Canada, France, Germany, Italy, Sweden, and the United Kingdom all have research programs on effects of electric fields. EPRI is in the process of establishing an informal international information exchange to avoid needless duplication and to encourage validation of results in different locales when deemed desirable.

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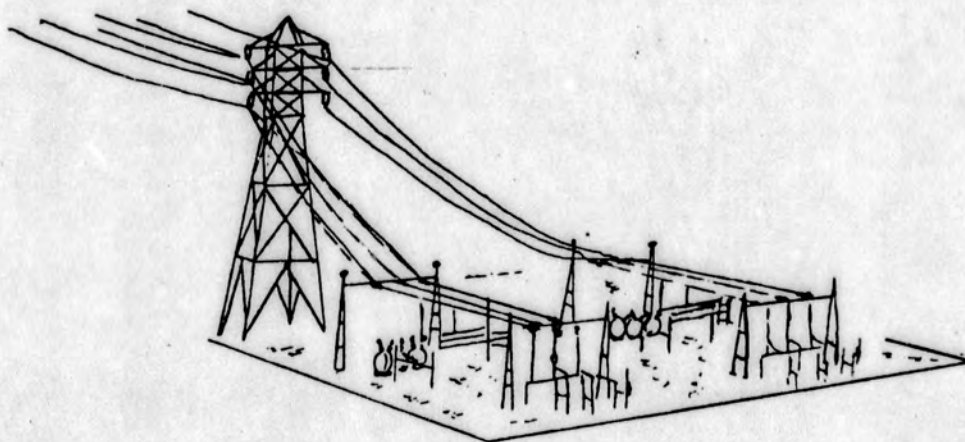
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ELECTROMAGNETIC FIELDS AND LIFE

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"Only a few of the invisible radiations are known to us at present. We have hardly begun to realize their diversity and the scrappy nature and inadequacy of our knowledge of the radiations which surround us and pass through us in the biosphere, and to understand their basic role in the processes going on around us, a role which is difficult to comprehend by minds accustomed to other conceptions of the universe. . . ." "We are surrounded and penetrated, at all times and in all places, by eternally changing, combining and opposing radiations of different wavelengths — from ten millionths of a millimeter to several kilometers."

V. I. Vernadskii, 1926

INTRODUCTION

Since the above lines were written science has learned much more about the electromagnetic radiations which have been present in the biosphere — the region which living organisms inhabit — throughout the whole epoch of evolution. Scientists have discovered more and more new natural electromagnetic radiations in various ranges of the electromagnetic spectrum. To the long-investigated range of solar radiations — infrared to ultraviolet — we have now added ionizing radiations (x rays and γ rays) of cosmic and terrestrial origin. In the remaining lower-frequency region of the electromagnetic spectrum, the discovery of the slow periodic variations (seasonal, monthly, diurnal) of the earth's magnetic and electric fields was followed by the discovery of the short-period fluctuations of the earth's magnetic field with frequencies extending to hundreds of hertz. The investigation of atmospheric discharges has shown that the electromagnetic radiations produced in this case cover a wide range of wavelengths — from superlong to ultrashort. Finally, radio emission in the range of meter to millimeter waves from the sun and the galaxies has been discovered.

Thus, it has now been established that periodic electromagnetic processes with frequencies distributed throughout the known

electromagnetic spectrum are a permanent feature of the biosphere. Hence, it can be postulated *a priori* that any region of this natural electromagnetic spectrum might have played some role in the evolution of living organisms and that this will be reflected in some way or other in their vital processes. We can say that any region of the spectrum is biologically active in some degree. In the general case three kinds of activity are probable:

1. The effect of electromagnetic processes taking place in the environment on the functioning of living organisms.
2. The role of electromagnetic processes taking place within organisms in the vital activity of organisms.
3. Electromagnetic interconnections between organisms.

For the spectral region where $h\nu > kT$ (at temperatures characteristic of living organisms), i.e., from the infrared range to gamma rays, these kinds of biological activity have already been discovered to some extent. It is known that photobiology is concerned not only with the reaction of living organisms to infrared, visible light, and ultraviolet rays, but also with the role of radiations of these ranges in processes occurring with organisms and "light-mediated interaction" between organisms. Radiobiology is concerned at present only with the biological action of x rays and gamma rays,* but "internal radiation" has also been discovered, although its role in biological processes has not yet been elucidated. Some recent investigations indicate the possibility of "radiation-mediated interactions" between organisms.

The situation is different with the remaining vast region of the electromagnetic spectrum, where $h\nu < kT$; this region includes the ranges from super-high to ultralow frequencies, right down to "zero frequency" (constant electric and magnetic fields). For convenience of exposition we will henceforth call this whole region of the spectrum "electromagnetic fields"† or EmFs. The problem of the biological activity of EmFs as a whole has only begun to take shape in recent years, although investigations of individual aspects of this problem has been carried out some time ago.

* We exclude here the corpuscular kinds of radiation (α - and β -rays, neutron fluxes), since we are dealing only with electromagnetic radiations.

† This term is arbitrary, of course, since all the rest of the spectrum also consists of electromagnetic fields.

Galvani's experiments in the 18th century initiated the development of electrophysiology (electrobiology), which deals with the reactions of living organisms to electric stimuli and with electric phenomena in organisms themselves. Using the terminology which we have adopted we can say that electrophysiology is the study of the first and second kinds of biological activity of EmFs, mainly in the low-frequency range and mainly in the case of contact application (or withdrawal) of electric energy. Galvani, however, was also first to discover a long-distance electric effect when he observed the contraction of the muscle in a frog nerve—muscle preparation situated at some distance from the spark of an electrostatic machine. Such experiments on electric stimulation of nerve at a distance were not taken up again until the end of the 19th century. At this time there also appeared the first reports of the biological effects of a magnetic field and high-frequency fields. In 1900-1901 there appeared V. Ya. Danilevskii's two-volume monograph dealing with the main experimental and theoretical principles of the biological action of EmFs on biological objects — from cells to entire organisms.

In the thirties and forties research on the effect of high- and ultrahigh-frequency EmFs on the human and animal organism was greatly extended (Libezin, 1936). Frenkel and Tatarinov, 1939; Proceedings of the Conference on the Application of UHF in Medicine, 1940; Shcherbak, 1936). The researchers encountered two kinds of biological effects from EmFs. There was a clear demonstration of the thermal effect — heating of the tissues of the organism or the biological substance in vitro due to EmFs of fairly high intensities; there were less definite effects which could not be attributed entirely to heating and also effects due to low-intensity EmFs, where no heating of the tissues was detected. Such "non-thermal" effects (which were often unwisely called "specific" effects) were observed mainly in the reactions of entire organisms, more rarely in isolated organs, and hardly ever in experiments with macromolecular solutions in vitro.

A possible role of natural EmFs in living nature has been categorically rejected on the basis of the following theoretical considerations.

Any possible effect of EmFs on biological objects, as on non-living objects similar to them in electrophysical properties, must

be due to particular energetic interactions of the EmF with the substance, i.e., conversion of the electromagnetic energy to other forms such that the resultant effect depends on the effective energy of the EmF. But the conversion of the EmF energy into other forms of energy in living tissues can involve only the same processes as in electrolyte solutions of corresponding composition. As regards the effect of a constant magnetic field, living tissues must be regarded as a weakly magnetic substance. Moreover, the energies of quanta in the EmF region are sufficient only to cause vibrations of charged particles as a whole — ions, dipole molecules, and colloidal micelles — in biological media. Such processes represent the only possible interaction of EmFs with biological media and result in the conversion of the electromagnetic energy to heat energy. However, for the induction of any biologically significant thermal effect the strengths of the acting EmFs must be several orders greater than those of natural environment EmFs of corresponding frequency. The biological effects of a constant magnetic field can be due to the orientation of paramagnetic and diamagnetic molecules. Such effects are possible only if the energy of the magnetic field, calculated per molecule, exceeds kT . For this the intensity of the field must be at least ten thousand times greater than that of the geomagnetic field.

The experimental data indicating changes in physiological processes in entire organisms due to exposure to much weaker EmFs were regarded as unconvincing for the following reasons. Firstly, organisms can respond with similar changes to diverse external factors and, hence, there are no grounds for postulating a "specific" biological effect of EmFs; secondly, if there was such an effect it would certainly be detected in experiments with physicochemically homogeneous media or, at least, in experiments with very simple biological systems, but such attempts were unsuccessful. Thus, physicists concluded that weak EmFs were incapable of producing biological effects.

In spite of these categorical conclusions biologists continued with experimental attempts to detect biological effects due to EmFs and constant magnetic fields with strengths much lower than the theoretically predicted effective values. Within the last ten years these attempts have produced successful results, which give grounds for believing that natural EmFs have probably been implicated in

the evolution of life and play a significant role in the vital activity of organisms. One cannot help recalling in this connection the words of Szent-Gyorgyi (1960) that "the biologist depends on the judgement of the physicist, but must be rather cautious when told that this or that is improbable."

Biological investigations have shown that organisms of the most diverse kinds — from unicellular organisms to man — are sensitive to a constant magnetic field and EmFs of different frequencies with an effective energy tens of orders (1) less than the theoretically estimated effective level. Hence, such estimates, based on the concept of the energetic interaction of EmFs with the biological substance, obviously lack a sound basis. This concept is also contradicted by the fact that instead of the predicted proportional relationship between the biological effects and the intensity of the acting EmFs quite different relationships have been experimentally established. It has been found that in some cases the reactions of living organisms to EmFs occur only at certain "optimum" intensities, in other cases the effects increase when the intensity of acting EmF is reduced, and in other cases the reactions to low and high intensities are of opposite nature. "Cumulative" biological effects produced by repeated exposure to EmFs well below the effective threshold for a single exposure have also been observed. Finally, the concept of energetic interaction is contradicted by the fact that for the same average EmF energy absorbed in the tissues of organisms the nature of the reactions depends considerably on the modulation of the EmF, on the directions of the electric and magnetic vectors of the EmF relative to the animal's body axis, on the localization of the exposure, and so on.

This has given rise to the need for a fundamentally new theoretical approach to the problem of the biological activity of EmFs — a theory which will not only be consistent with the experimental data but will provide a basis for their interpretation and an elucidation of the particular mechanisms involved. Such an approach can be based on information theory.

The application of this theory to biology has shown that, in addition to energetic interactions, informational interactions play a significant (if not the main) role in biological processes. Such interactions entail the conversion of information, its

transmission, coding, and storage. The biological effects due to these interactions do not depend on the amount of energy introduced into the particular system, but on the amount of information introduced into it. The information-carrying signal merely causes the redistribution of the energy in the system itself and regulates the processes occurring in it. If the sensitivity of the receiving systems is sufficiently high very little energy is required for information transfer. The information can be built up in the system by the repetition of weak signals.

The informational aspect of the interaction of EmFs with biological objects must be taken into account even in the consideration of such obviously energetic effects as thermal effects. These effects are due not only to an increase in the kinetic energy of chaotic motion of the molecules, as in normal heating (convection, infrared radiation), but also to coherent vibrations of the molecules and ions with the same frequency as the acting EmF. In biological systems with oriented molecular layers and ordered motions of the microparticles such an imposed rhythm can be regarded in general as the introduction of "harmful" information into the system.

The information approach to the biological action of EmFs is even more essential in the case of very low intensities, where any energetic effects are theoretically impossible. Informational interactions of EmFs with biological systems can account for the high sensitivity of living organisms to EmFs, the specific relationship between the biological effects of EmFs and their intensity and modulation, and the cumulative effect of EmFs.

It is a valid assumption that all these special features of the reactions of living organisms to EmFs are associated with certain biological systems formed in the process of evolution for the reception of information from the environment. This hypothesis has already received experimental verification. It has been found that the periodic variations of natural environmental EmFs have a regulating effect on vital functions — on the rhythms of the main physiological processes, on the ability of animals to orient themselves in space, on multiplication in populations, and so on. In the living organism the systems for receiving information transmitted by EmFs are reliably shielded from natural electromagnetic interference, but in pathological states spontaneous variations of EmFs

(solar flares, lightning discharges) upset the regulation of physiological processes.

It appears that in the process of evolution living nature has used EmFs to obtain information about the changes in the environment. The EmF, of course, is the most reliable information-carrier among geophysical factors. By means of EmFs information can be transmitted (in the appropriate frequency ranges) through any medium inhabited by living organisms and in any meteorological conditions — during the polar day or night, in river and sea water, within the earth's crust and, finally, in the tissues of organisms themselves.

Thus, the first kind of biological activity of EmFs — the effect of environmental EmFs on the functioning of living organisms — acquires reality in the light of the results of biological investigations and their interpretation on the basis of the concept of the informational interactions of EmFs with biological systems formed in the process of evolution.

Experimental data which indicate the existence of the second kind of biological activity of EmFs — their implication in informational interconnections within the organism — have now been obtained. There is not only the already known transmission of information along the nerves by bioelectric pulses with a frequency spectrum extending to thousands of hertz, but also the long-range interactions effected by EmFs of very different frequencies — from infrared to superhigh frequency (we will henceforth call these EmF-interactions or EmF-connections). They are manifested in the electromagnetic interrelationships between macromolecules, in the synchronization of the electromagnetic vibrations in assemblies of macromolecules and groups of cells, and so on. It is hoped that the concept of EmF-connections may clarify the hitherto baffling nature of some long-established selective interactions between cells and macromolecules.

Finally, there are data which suggest the existence of the third kind of biological activity of EmFs — informational interconnections between organisms. On one hand, animals are particularly sensitive to EmFs with parameters (frequency, intensity, pulse modulation) in a fairly narrow range. On the other hand, it has been found that living organisms are sources of EmFs of various

ranges — from infralow to superhigh frequency. Finally, exposure of human beings to EmFs gives rise to definite sensations — visual, auditory, and tactile. The concept of informational EmF-connections in the animal world may prove fruitful in several cases where there is clearly an exchange of signals between animals, but the physical nature of the signaling process has not yet been determined.

An analysis of the experimental data which indicate the appearance of these kinds of biological activity of EmFs leads to the conclusion that it is useless to attempt to seek the causes of such properties of life only at the molecular level or to proceed from a consideration of the processes arising at this level due to EmFs. This is most obvious from investigations of the effect of external EmFs on biological objects.

It has been found, for instance, that entire organisms are most sensitive to EmFs, isolated organs and cells are less sensitive, and solutions of macromolecules are even less sensitive. Significant differences are observed in the reaction of one biological system (molecular, cellular, organic, or systemic) to EmFs in relation to the conditions in which the action takes place — whether it is in the entire organism or in the isolated state. In these two cases there is also a difference in the nature of the relationship between the reaction of the system and the parameters of the EmF.

All this indicates that the systems which are particularly sensitive to EmFs have presumably been formed in the process of evolution only at the macroscopic level, beginning, at the lowest, from ordered macromolecular assemblies. In other words, the property of receiving weak natural EmFs appears only at the level of fairly complexly organized biological systems and this property is probably manifested to the full extent only in the entire organism.

The appearance of enhanced sensitivity to EmFs only in fairly complexly organized biological systems, can be regarded as one of the manifestations of the specific nature of life — its "organization." We cite some current views on this subject.

Shmal'gauzen (1964) says "... the functions of a higher system are not a summation of the activity of lower systems, but their integration. Each higher system reveals its own qualitative

specificity, which is created only by the organization of this higher system."

Szent-Gyorgyi (1960) says "One of the basic principles of life is "organization" by which we mean that if two things are put together something new is born, the qualities of which are not additive and cannot be expressed in terms of the qualities of the constituents."

Schmitt (1959) speaks of "hierarchies of organization and with the properties that are characteristic of systems . . . at each particular level of organizational complexity, viz., molecular, macromolecular, subcellular, cellular, supercellular, organismic, and superorganismic." Further, ". . . there is a formidable "black box" between the molecular effectors, as studied in the model system, and the final behavior of the cells or organism under study."

It has been pointed out on occasion that such integration occurs also in nonliving nature — in the systems of elementary particles forming atoms and in the combination of atoms to form molecules. At these levels, however, there is no difference between nonliving and living matter: The atoms and molecules are organized in the same way in each case. The difference appears only at the "supermolecular" level — in the specific nature of the organization of the macromolecules and their assemblies, and in the hierarchy of the systems comprising the living organism. Here we encounter the integration of properties which has no analogy in nonliving nature.

We have made this excursion into the problem of the specificity of life, since up till now the common approach to the investigation of the biological effect of EmFs has been one in which effects at the molecular level in physicochemically homogeneous systems are first investigated and only after this are the more complexly organized structures examined. There is still a sceptical (and usually negative) attitude to any results of experiments on entire organisms and even on isolated organs. Such views are the result of excessive enthusiasm over the undoubtedly significant successes of "molecular biophysics" and the neglect of the historical fact that the investigation of the interaction of living organisms with any external factor began with observation of the reactions of

the entire organism and only after this were the systems involved in these reactions revealed.

Yet the reverse procedure is the practical one: To investigate first the reactions of the entire organism to EmFs, and then to go on from there to determine the simplest level of organization at which it is still possible to detect the changes which are ultimately responsible for the particular reaction of the organism. The prime cause of the reaction need not necessarily be due to processes at the molecular level — it may be a feature of some macroscopic level of organization. There is nothing paradoxical in this — we encounter such a situation in the examination of "organized" machine systems, which are also characterized by the presence of a hierarchy of order and the appearance of new properties with increase in complexity.*

This can be illustrated even by the example of such a relatively simple system as the oscillatory circuit. The specific feature of this circuit is its particularly high sensitivity to an EmF of a particular (resonant) frequency. Of course, the electromagnetic oscillations induced in the circuit are due to microprocesses — motion of electrons in the wires and the polarization of the molecules in the dielectric of the capacitor. But attempts to discover the mechanism of resonance at this level will be in vain — it is not there. Nor can we detect this property by considering the processes in separate macroscopic elements of the circuit — the capacitor and the induction coil. The property of resonance is a feature only of the whole organized system — the circuit as a whole.

Thus, the phenomenological approach to the investigation of the systems and processes involved in the reactions of biological objects to EmFs is the practical one at present. We can determine only the regular relationships between the "input" and "output" characteristics of the system, i.e., between the operating factors and the reactions. It is quite in order to simulate such systems and processes by means of equivalent electromagnetic "organized systems", exhibiting corresponding input and output charac-

*This may be the result of a historically manifested law which McCulloch (1962) expounds in the following way: "But aside from sources of power, and from the wheel, most of what we have done has been an imitation (of animals)."

teristics, the relationship between which is described within the framework of the macroscopic parameters. In this way we can, for instance, approach an explanation of the high sensitivity of biological systems to EmFs, i.e., their ability to receive the information carried by EmFs of very low intensity (even below the noise level).

Information theory indicates the possibility of "spatial summation" of electromagnetic informational signals received simultaneously by n elements and of "temporal summation" of signals repeated n times. In either case the total signal-to-noise ratio is increased by a factor $\sqrt{n}$. Hence, if n is sufficiently large the reception of information with a signal intensity below the noise level is possible. Reception has been effected in technical systems of such kind. The two types of summation are also found in living organisms — in the visual organs for electromagnetic light waves (Glezer and Tsukerman, 1961) and in nerve cells for low-frequency electromagnetic signals. Hence, the existence of such biological systems for the reception of EmFs of other frequency ranges is probable.

The main information on the input and output characteristics of biological systems sensitive to EmFs has been obtained mainly from investigations of the reactions of entire organisms to EmFs. However, to seek certain specific reactions is "to pursue a will-o-the-wisp": to adequate informational action of EmFs and to electromagnetic noise the reactions are nonspecific — the same reactions can be produced by other external factors.

For instance, regulation of the daily rhythm of physiological processes is effected by various geophysical factors, probably equally. The role of periodic environmental EmFs in this regulation can be determined only by a correlation analysis, either by artificially maintaining other geophysical factors constant, or by investigating changes in the rhythm of physiological processes when the environmental EmFs are artificially attenuated.

The disturbances of physiological processes — changes in intensity, direction, etc. — due to electromagnetic interference must also be nonspecific. The same kind of disturbances can be produced by the action of other factors — mechanical, chemical, biological, etc. The disturbance of the function of any organized

system is nonspecific in the sense that its nature is often independent of the type of interference. For instance, the same noise can be produced at the output of a radio receiver by radio interference (natural or artificial) or by faulty contacts — mechanical or chemical.

These remarks on the approach to the investigation of the biological action of EmFs apply also the EmF-interconnections within the organism. Interactions between macromolecules and between cells and, even more so, between more complex biological systems cannot be understood at present without regard to the role of "organization" at all these levels and without regard to the differences in the course of the corresponding processes in the organism and in systems isolated from it.

As regards the investigation of the problem of EmF-interconnections between animals, even investigations of entire organisms may be inadequate. Since associations in groups, communities, populations, and biocenoses exhibit their own specific features due to "coalition" (von Foerster, 1962) — "an aggregate of elements which jointly can do things which all of them separately could never achieve". Hence, the investigation of the EmF-interconnections in animal associations will require an analysis of a vast amount of material collected by zoologists, ecologists, and ethologists. In this respect the method of empirical generalization, proposed by Vernadskii (1926), may prove to be very effective. This method, which is based on inductively obtained facts, does not go beyond the limits of these facts and is not concerned with the consistency or inconsistency of the obtained conclusion with other existing ideas on nature. In this respect empirical generalization does not differ from scientifically established fact: Their agreement with our scientific ideas on nature does not interest us, their contradiction of them is a scientific discovery.

Such briefly are the general arguments and experimental evidence which have led us to pose the problem of the role of EmFs in life. In fact, in addition to previously developed fields of biology — photobiology and radiobiology, which are concerned with the biological activity of electromagnetic radiations from infrared to gamma rays, there is now developing a new branch of biology dealing with the biological activity of the remaining region of the elec-

tromagnetic spectrum — from superhigh to "zero" frequency (constant fields). We suggested earlier (Presman, 1965a) that this branch, which brings together a wide circle of problems relating to various manifestations of the biological activity of EmFs, should be called electromagnetic biology (for lack of a more suitable term).

The basic tenets in the formulation of the problem are: 1) the concept of the informational functions of EmFs in life at all levels of its hierarchical organization and 2) the conviction that the investigation of these functions of EmFs must proceed from complex biological systems and processes to more and more simple systems and processes.

The aim of this book is to substantiate this concept and methodology from the abundant experimental material on the diverse biological effects of EmFs. I have tried to carry out this analysis as objectively as possible, but I admit that, being the author of this concept, I have found it difficult to avoid partiality in the assessment of the experimental data which I have examined and the derivation of conclusions from them.

In such a case it is particularly valuable to have the opinion of impartial scientists as to how far the author has managed to retain sufficient objectivity in the exposition and substantiation of his views. For such a critical evaluation of the manuscript of this book, and for valuable advice and comments I am deeply grateful to Academician V. V. Parin and Professors L. A. Blyumenfel'd, P. I. Gulyaev, and S. É. Shnol'.

Return to W. Brockley
St. Peter, MN

Phys-B
27

1 BEFORE THE STATE OF NEW YORK

2 PUBLIC SERVICE COMMISSION

3 -----

4 CASES 26529 and 26559 - Common Record :
5 Hearings on Health and Safety of :
6 765 kV Transmission Lines. :
7 -----

7

8

Prepared Testimony of
Robert O. Becker
Veterans Administration Hospital
Irving Avenue
Syracuse, New York

9

10

11 Q. Would you state your name and business address?

12 A. Dr. Robert Becker, Veterans Administration Hospital,
13 Syracuse, New York.

14 Q. Would you summarize your educational and professional
15 background?

16 A. I am a doctor of medicine, having received my MD degree
17 from New York College of Medicine in 1948. In 1959 I
18 became a Diplomate of the American Board of Orthopaedic
19 Surgery, having completed the necessary advanced training
20 at Downstate Medical Center, SUNY. I have been Chief
21 of Orthopedic Surgery at the VA Hospital, Syracuse, since

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1 1956, and have been Professor of Orthopedic Surgery,
2 SUNY, Upstate Medical Center since 1963. I have been
3 engaged in medical research since 1958 with particular
4 interest in electronic biological control systems. I
5 have published more than 70 scientific papers and given
6 more than 75 presentations at national and international
7 scientific meetings. In 1964 I was awarded the William
8 S. Middleton Award of the Veterans Administration for
9 research in biological solid state physics and biological
10 control systems. I was presented with the Distinguished
11 Alumnus Award from NYU, College of Medicine in 1966. I
12 became a Medical Investigator with the VA in 1972, a
13 position enabling me to devote full time to research.

14 Q. Are you the director of a research laboratory?

15 A. Yes. I am the director of the Orthopedic-Biophysics
16 Laboratory at the Syracuse VA Hospital-Upstate Medical
17 Center. The staff varies between 10 and 16 people
18 depending upon such things as the number of students on
19 elective, the number of visiting scientists spending
20 their sabattical year with us, etc. The present staff
21 includes three Ph.D biophysicists, one Ph.D anatomist,

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1 two M.D.s (orthopedic surgeons) and a variety of
2 technical personnel.

3 Q.. Would you briefly describe the nature of your research?

4 A. In brief, our research is aimed at elucidating the
5 details of the control systems that living organisms
6 utilize to direct certain basic life functions such as
7 growth and healing, biological cycles, etc. We have
8 determined that living organisms possess certain electric
9 control systems characterized by the use of very small
10 electrical currents and voltages as control signals.
11 These are derived from certain solid state properties
12 of cells and tissues such as semiconductivity, piezo-
13 electricity, etc. At this time our discoveries are being
14 used to stimulate the healing of non-united fractures and
15 to treat certain types of infectious processes in the
16 human by the application of small electrical currents which
17 stimulate those which naturally occur. This work is going
18 on at several medical centers including Syracuse. Other
19 research groups are also using small electrical currents
20 to relieve pain, produce surgical anesthesia or sleep
21 and as additive treatment to acupuncture.

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1 Because of the physical nature of the biological
2 electronic control system, we predicted that external
3 electromagnetic fields should produce physiological
4 and functional changes in living organisms. We have
5 been conducting research using a variety of such fields
6 and a variety of experimental animals for the past 15
7 years. The results of these experiments have conclusively
8 indicated that such fields do have an effect upon living
9 organisms.

10 Q. What is the purpose of your testimony?

11 A. I will discuss the medical and biological significance
12 of exposure to low frequency electric and magnetic fields.
13 My testimony will encompass both the published reports and
14 the latest results of our own research. I will testify
15 that an electric field at 60 Hz is a biological stressor.
16 I will discuss the question of medical ethics involved
17 in exposing human beings to electric fields. My testimony
18 will conclude that the transmission line should not be
19 built as proposed.

20 Q. Would you comment on the medical significance of the reports
21 described by Dr. Marino dealing with ELF effects?

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1 A. Before answering this specifically, I would like
2 to point out that the majority of these reports came
3 from the refereed scientific literature. That means
4 before they were published, they were reviewed by
5 scientific experts in the specific area concerned, and the
6 experimental set-up and techniques used were judged to be
7 both appropriate and rigorous enough to have yielded
8 valid data. Such reports cannot be lightly dismissed.
9 The first and most obvious conclusion to draw
10 is that ELF electric fields do have biological ef-
11 fects, some at extremely low field strengths. In
12 general, the reports fall into two main categories,
13 and one minor category. The first main category is
14 growth effects. These include tumor growths, accelerated
15 healing rates, both increased and decreased mitotic
16 rates and abnormalities in development. There are
17 some apparent inconsistencies in the reports; how
18 can the same physical modality produce at one time,
19 bone tumors, an undesirable effect, and at another
20 time, accelerated rate of healing of bone fractures,
21 an obviously desirable effect? The answer lies in

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1 the fact that the biological response to such a
2 parameter is determined much by the state of the
3 living specimen when it is exposed. Normal unbroken
4 bones exposed to 3 or 30 Hz fields developed tumor
5 growth. Bones with fractures, in which
6 a healing response of increased cellular growth
7 has been switched on, when exposed to 65 Hz fields,
8 showed an increase over the normal rate of healing.
9 Obviously, the two experiments involved two dis-
10 tinctly different biological states and there is no
11 contradiction between the reports at the basic level.
12 It would appear valid to postulate upon the basis
13 of these reports that growth disturbances could
14 result from exposure to ELF fields strengths or
15 frequencies outside of the norm. It may be wise
16 to comment upon the fact that only one report
17 presents the occurrence of tumors following such
18 exposure. Why are there no confirmatory reports
19 from other workers who similarly exposed animals?
20 The answer lies in the nature of scientific research.
21 The investigator operates on a limited budget and

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1 within a specific frame of reference. If he is
2 interested in the use of such fields to obviate
3 the osteoporosis of the bone that accompanies im-
4 mobilization, you will carefully examine the bones
5 following exposure. He will however, have neither
6 the funds nor cooperating scientific personnel to
7 examine all other organs and tissues of the animals
8 for the occurrence of tumors therein. For example,
9 in our own series of experiments described by Dr.
10 Marino, we were fully aware of McElhaney's report
11 and we are familiar with bone physiology, yet we
12 structured our experiment around another thesis,
13 that of the stressor effect. We could accomplish
14 that with our limited funds and it would be more sub-
15 stantive to our overall scientific objective than
16 would a repeat of McElhaney's experiments. While
17 we would have liked to autopsy our experimental
18 animals for tumor growths, we lacked both funds and
19 personnel to do so.

20 The second main category of effects can be
21 classified as functional. In this type of response,

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1 the exposure to the field produced a change in
2 the way the organism worked. Such changes can be
3 produced without any noticeable change in the appearance
4 either of the total animal or of its tissues when
5 studied under a microscope. Functional responses
6 have included strictly behavioural effects, such as
7 the avoidance of a field irradiated area, orientational
8 effects within a field, and alterations in response
9 times. Two reports dealt with alterations in the
10 electrocardiogram and the electroencephalogram.
11 Both the heart and brain utilize electrical energy
12 in their operation and such interferences may be
13 predicted. A basic aspect of function is the
14 phenomenon of biological cycles and two extremely
15 precise sets of experiments have indicated a sensitivity
16 of this function to such applied fields. The medical
17 significance of functional changes such as these have
18 been well described in the Russian literature relating
19 the complaints of occupationally exposed
20 workers. These complaints all fall within the functional
21 frame of reference and appear related to effects upon

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1 the central nervous system and the cardiovascular
2 system. Such complaints are also concomitant with
3 stress and indeed the stress response may be integral
4 with other central nervous system symptoms.

5 The minor category includes two reports, one
6 Russian, one American, both presenting data on
7 the death of cells or total organisms accompanying
8 exposure to very high strength fields. The state of
9 knowledge in this area at present does not permit us
10 to speculate upon the pathophysiology that might have
11 been involved.

12 To sum up, from the viewpoint of possible medical
13 significance, the literature reports represent a solid
14 body of data indicating that living organisms are in-
15 fluenced by ELF fields, and that such effects are likely
16 to occur in the areas of growth, both cellular and of
17 the total organism, and in the function of the central
18 nervous system and cardiovascular system. Obviously,
19 to answer specific questions, such as the effects of
20 various field strengths at 60 Hz upon the variable
21 human population, will require specific laboratory

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1 experimentation. These answers are not available
2 at this time.

3 Q. Do the results of your research on electric field
4 exposure at 60 Hz as described by Dr. Marino indicate
5 that the rats were subject to biological stress?

6 A. The condition of the rats at the end of 30 days exposure
7 was consistent with chronic exposure to an environmental
8 stressor. Chronic stress has been linked to cardiac
9 (hypertension), renal (nephritis), gastro-intestinal
10 (ulcers) and nervous (psychoses) diseases. There is
11 some evidence that arthritis, particularly rheumatoid
12 type and certain vascular diseases such as periarteritis
13 nodosa may also be related. In addition, chronic stress
14 results in exacerbation of any pre-existing pathological
15 processes. There is extensive literature in this field
16 and since there are several phases of response to stress,
17 depending upon the length of exposure, I have limited
18 my response to chronic stress situations.

19 Q. Would you explain the distinction between the terms
20 "acute" and "chronic" as they are used medically?

21 A. Acute refers to a short term exposure, generally less
22 than one day and chronic refers to long term exposure,

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1 more than a day.

2 Q. What is meant by the term "stress" or "stressor"?

3 A. A non-specific biological stressor is any environmental
4 stimulus which causes systemic stress in an organism.

5 Systemic stress denotes a condition in which, due to
6 function or damage, extensive regions of the body
7 deviate from their normal resting state.

8 The stress response in the organism is basically
9 produced by alterations in the function of the pituitary
10 and adrenal glands. Presumably the initial response is
11 in the central nervous system - most probably the brain -
12 with information being transmitted to the pituitary gland
13 which is directly connected to the brain.

14 The actual physiological changes resulting from
15 exposure to a stressor are determined not only by the
16 nature of the stressor itself, but also by factors within
17 the stressed organism, such as the level of nutrition,
18 concurrent stressful conditions, the presence of pre-
19 existing disease states, heredity and previous conditioning
20 experiences.

21 The actual total stress response produced by chronic

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1 exposure to a stressor is called the General
2 Adaptation Syndrome and is divided into three
3 stages. The first is called the Alarm Reaction,
4 in which the adrenal glands enlarge, lymph nodes
5 and thymus gland decrease in size and gastric ulcers
6 appear. The levels of hormones secreted by the active
7 glands are increased. In the second stage, that of
8 Adaptation, the hormone levels return to normal and
9 the animal does not appear to be responding to the
10 stress. In the final phase, that of Exhaustion, the
11 level of the active hormones decrease below normal,
12 and the organism is less capable of responding to the
13 stress. Dr. Hans Selye, who first described the stress
14 adaptation syndrome, has been able to correlate chronic
15 stress with certain disease states including collagen
16 diseases, periarteritis nodosa, renal arteriosclerosis,
17 hypertension and gastric ulcers.

18 Q. It is occasionally said that stress is "good for you".
19 Do you agree?

20 A. If stress is "good for you", then it is the biological
21 response to stress that is "good for you", since stress

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1 that does not elicit a response from the stressed
2 organism has no effect on its own.

3 There are two conditions under which the stress
4 response may be considered "good for you". It is
5 in fact, vital for the survival of life, having been
6 evolved from the earliest living organisms. When an
7 organism is stressed naturally, i.e., being pursued by
8 a predator, the stress response enables the animal to
9 use its body maximally to escape. The action of the
10 muscles and nerves is enhanced and the animal becomes
11 functionally capable of extra activity. Humans
12 experience a similar response when subjected to bacterial.
13 infections and in this case the increase in the activity
14 of the immune system is advantageous. Initially, the
15 physiology associated with such acute stress was termed
16 the "fight or flight" condition which is an apt
17 description. Therefore, under the conditions of acute
18 stress, the organism's functional ability is heightened.
19 We experience this occasionally in "being able to work
20 best under stress". The problem however, is two-fold.
21 First, there are indications from Dr. Selye's work that

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1 stresses are additive and that two stresses, neither
2 of which would be particularly harmful, when acting
3 in concert, will produce a pathological state.
4 Secondly, all of the good effects of the stress
5 response are limited to the alarm reaction phase of
6 the stress response. If the stressful condition con-
7 tinues, the alterations in body chemistry and function
8 that were advantageous in a "fight or flight" situation
9 begin to change and ultimately, in the stage of
10 exhaustion, the changes are reversed and the organism
11 is less able to function in an optimal fashion.

12 The "stress is good for you" concept is limited
13 to single short duration episodes of mild to moderate
14 stress and cannot be applied to the situation of multiple
15 stresses or long-term chronic stress.

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1 Q. Could people sustain the same effects as the rats, if
2 comparably exposed?

3 A. Yes. I know of no significant difference between rats
4 and men in terms of their reaction to stress.

5 Q. Assuming that the electric field distribution due to the
6 proposed transmission line is as Dr. Deno has calculated,
7 does it present a danger, from a health viewpoint, to
8 either maintenance personnel or persons living near the
9 edge of the right-of-way?

10 A. Utilizing the safety factor of 100 in connection with our
11 research, the field strength within the proposed right-of-
12 way and for a distance out on either side would exceed
13 the safe level (1.5 volts/cm). Maintenance personnel would
14 probably be exposed to levels in excess of 1.5 volts/
15 cm for relatively short periods of time. Since our experi-
16 ments involve long term (30 days) exposure, we cannot say
17 whether or not such short exposures would produce any
18 biological effect. By the same token, we cannot say
19 whether or not any effects from such short time exposures
20 (if they did occur) would be cumulative and eventually
21 become clinically significant.

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1 In regard to persons residing near the right-of-
2 way and within the zone of field strength of 1.5
3 volts/cm or higher, they would run the risk of having
4 some biological effect induced as a result of this
5 exposure. Since the effects we noted experimentally
6 indicated that the field acted as a stressor, I would
7 have to assume that the effects would be harmful.
8 Again in regard to cumulative effects (dose related in
9 this case, i.e., lower field strengths at greater dis-
10 tances with long term exposures) we cannot make any
11 statements at this time.
12 Q. Would you recommend against the public periodically
13 using the right-of-way for less than a day for such
14 activities as farming, logging, hiking, camping,
15 hunting, etc.?
16 A. In general, I would be opposed to the multiple use
17 concept until the extent of the biological hazards was
18 ascertained. In specific, it certainly seems prudent to
19 discontinue recreational use. In the case of economic
20 use, farming, etc. involving short term exposures, it
21 may be possible to continue such usage provided the

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1 potential risks are made evident. In regards to
2 the question of short term exposure to maintenance
3 personnel, perhaps the present Russian regulations
4 might be applied.

5 Q. Would it be unsafe to permit people to occupy
6 residences within 329 feet of the centerline of the
7 proposed lines if the electric field within the
8 residence is less than 1.5 volts/cm?

9 A. We cannot answer this question at this time, not
10 knowing the effects of chronic exposure to fields
11 lower than we have employed in our experiments to date.

12 Q. Is it likely that different individuals will react
13 differently to the same degree of exposure to the
14 electric fields from these lines?

15 A. Yes.

16 Q. Would a person subject to long term exposure to electric
17 fields from these lines be likely to discern effects
18 from such exposure?

19 A. I believe that the weight of the evidence indicates that
20 biological effects would occur. Such effects would be
21 within the framework of the stress Adaptation Syndrome

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1 and may be evidenced in a variety of fashions, from
2 such functional changes as increased irritability
3 and fatigue, to such actual pathological states as
4 hypertension and stomach ulcers.

5 Q. Could a medical doctor diagnose the electric field
6 from 765 kV lines as the causative agent for certain
7 stress related-illnesses?

8 A. Given the present level of knowledge and the absence
9 of any other causative factors, I believe that such a
10 diagnosis could be made with a reasonable medical
11 certainty.

12 Q. In your research, do you use human beings as subjects?

13 A. Yes, humans are presently used in our studies on
14 stimulating bone growth and retarding infectious
15 processes.

16 Q. Would you briefly describe the precautions taken
17 when humans are involved as subjects?

18 A. In the case of human experimentation, the present
19 regulations require that any proposed study be
20 reviewed in detail by a committee of experts including
21 medical and scientific personnel (it is further

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1 recommended that representatives of the clergy,
2 psychological sciences, and laymen be included on
3 the committee). It is the responsibility of the
4 committee to balance risks against gains of any
5 given experiment. In regard to risk, the nature
6 of experimental medicine is such that the possibility
7 that all risks may not be predicted in advance must
8 be entertained. In regard to gain, consideration
9 must be given to gain that may be experienced by the
10 experimental subject (i.e., possible healing of a
11 non-united fracture) and to general human gains in
12 terms of the collection of knowledge that may be of
13 value to others or to general biological understanding.
14 After consideration of these factors, the committee
15 must approve the proposed study. An investigator
16 cannot proceed without such approval. It is most
17 important to note that the key provision of present
18 human experimentation is informed consent. If the
19 committee approves the project, each subject must still
20 be fully apprised of all known possible risks, the
21 possibility of unknown risks and the possible gains

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1 (if any) he or she will accrue. Only under these
2 circumstances is human experimentation medically
3 proper.

4 Q. Would it be considered medically unethical to apply
5 small electric currents to humans for research
6 purposes without securing their permission?

7 A. Yes, it would be considered unethical in my opinion.

8 Q. Would it be considered medically unethical to apply
9 60 Hz electric fields to humans without securing their
10 permission?

11 A. Yes, it would be considered unethical in my opinion,
12 if the field strengths exceeded that to which we are
13 exposed in the normal course of everyday living (i.e.,
14 ~~normal household ambient levels~~). In that case human
15 experimentation committee approval and informed consent
16 would be required.

17 Q. Dr. Marino has discussed piezoelectric effects as a
18 possible mechanism of action of 60 Hz electric fields
19 on animals; are there any other biological mechanisms
20 that would enable 60 Hz electric fields to have an
21 effect on living organisms?

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1 A. As I indicated previously, we have, over the past 15
2 years, obtained evidence for the existence of electronic
3 biological control systems based upon solid state
4 properties of living materials. We know, for example,
5 that injuries result in specific electrical phenomena
6 at the site of injury and that these (very minute in
7 amount) electrical parameters in turn cause the cells
8 at the injured site to multiply and heal the injury.
9 This function is controlled by an overall biological
10 control system which is associated with, but separable
11 from, the central nervous system. Our evidence indicates
12 that this control system is based upon specific cells
13 (the perineural cells) and that it transmits information
14 by means of the actual flow of small direct electrical
15 currents, generated by solid state properties of these
16 cells. It may be likened to an analog computer system,
17 while the nervous system itself is similar to a digital
18 computer. This direct current system controls growth
19 and healing, as previously noted, and in addition, we
20 believe it may be related to the perception of pain.
21 There is evidence that biological cycles of behavior

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1 in all organs are linked to the same cyclic pattern
2 in the normal environmental electrical and magnetic
3 fields. The properties of this direct current system
4 are such that it would be influenced by such cyclic
5 changes in these environmental fields. It is believed
6 that this system may provide the necessary linkage
7 mechanism between the normal variations in these
8 geophysical parameters and the normal biological cyclic
9 rhythms. One of the primary characteristics of the
10 normal atmospheric electromagnetic field is its
11 associated extra low frequency (ELF) component.
12 These ELF fluctuations are in the region of from
13 1 to 20 cps with maximum power centered in the 10 cps
14 range. It is perhaps significant that the electro-
15 encephalogram contains the same frequencies and that
16 electroencephalograms of a wide variety of organisms
17 are basically similar. Electromagnetic waves in
18 this frequency range can be transmitted for great
19 distances with little loss in strength. It has been
20 proposed that, since all organisms arose and developed
21 within an environment that included these electromagnetic
22 fields and frequencies, they were a primary factor

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1 in providing the energy input for the origin of life
2 and that the coupling between living organisms and
3 them is a basic life function (Cole, F. and Graf, E.,
4 in Biologic and Clinical Effects of Low-Frequency
5 Magnetic and Electric Fields, Charles C. Thomas,
6 Springfield 1974). Some substantiation for this is
7 the fact that profound disturbances in the electro-
8 magnetic field such as magnetic field reversals,
9 occurring in the geologic past, were associated with
10 the death of many animals and the actual extinction
11 of some species (Hays and Updyke, Science 158,
12 1001 (1967)).

13 If the natural electromagnetic field is directly
14 linked to the organism via the electronic control
15 system we have described, then changes in the natural
16 field, including increased field strength and
17 frequencies not normally present would result in stress
18 in exposed organisms. Such stress responses would
19 come about by disturbances in the normal biological
20 cycles caused by the abnormal field exposure. Many
21 of the scientific reports quoted by Dr. Marino in

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1 his testimony are interpretable in this light.

2 Therefore exposure to electric fields differing
3 in frequency and/or in magnitude from the normal
4 earth's field may produce biological effects by
5 (1) inducing small electrical fields within the
6 tissues that could interfere with normal healing and
7 growth processes by presenting abnormal signals to
8 the cells (under certain circumstances such induced
9 currents may be beneficial, i.e., in stimulating the
10 healing of non-united fractures) and (2) by interferring
11 with the normal biological cyclic rhythm through
12 interaction with the electric system linking organisms
13 to the geophysical environment. This latter effect
14 would be evidenced as a response to stress and with
15 prolonged exposure as the stress adaptation syndrome.

16 Q. Does your research involve magnetic fields?

17 A. Yes. I have used magnetic fields primarily as a tool
18 to probe the workings of the direct current control
19 system.

20 Q. Have you published in this area?

21 A. I have reported effects of external magnetic fields