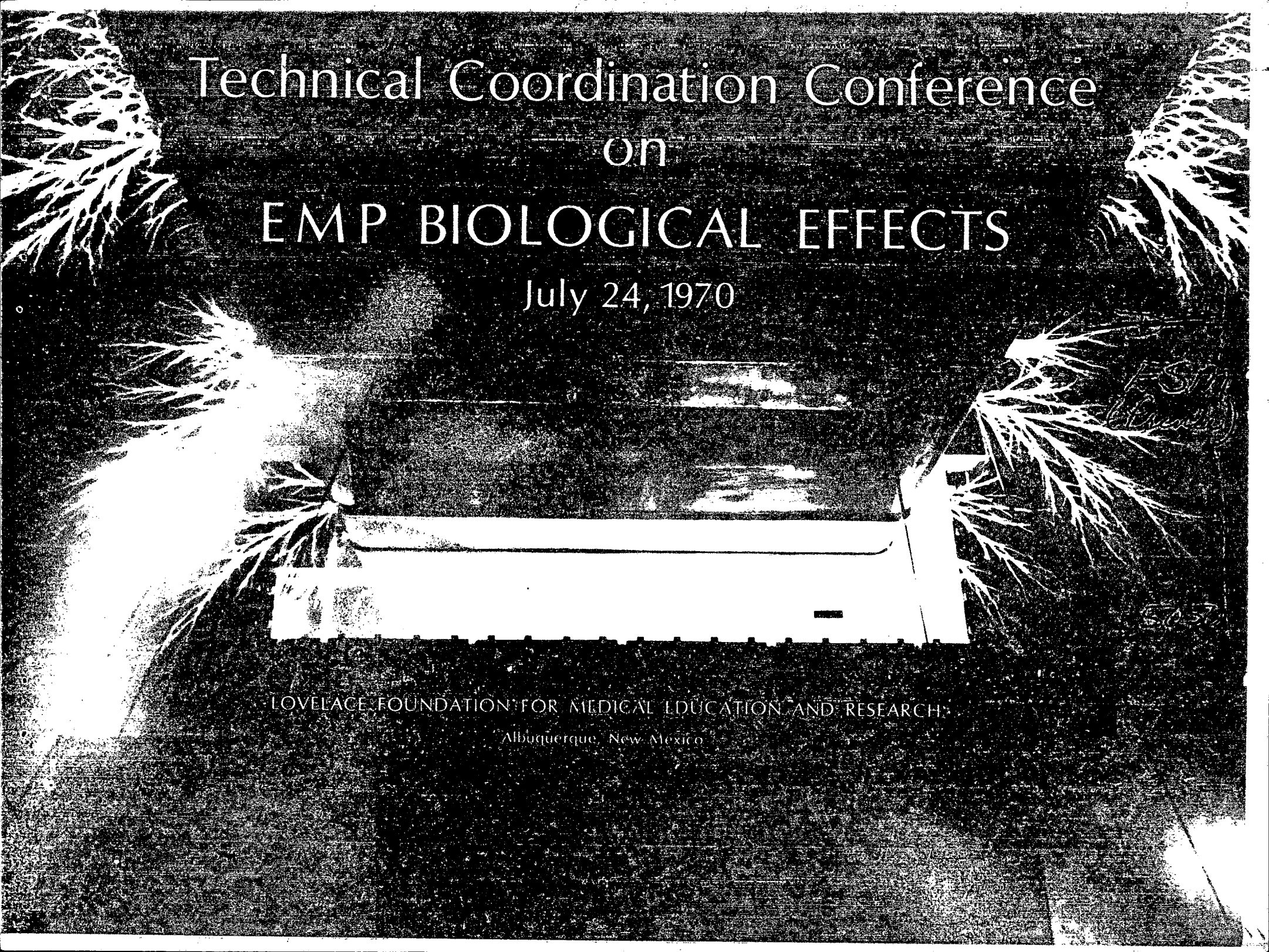
Technical Coordination Conference on EMP BIOLOGICAL EFFECTS

July 24, 1970



LOVELACE FOUNDATION FOR MEDICAL EDUCATION AND RESEARCH
Albuquerque, New Mexico

Proceedings of the

Technical Coordination Conference on EMP Biological Effects

July 1970

Chairman
F. G. Hirsch, M.D.

Co-Chairman
A. Bruner, Ph. D.

Sponsored by
The Lovelace Foundation for Medical Education and Research
Albuquerque, New Mexico

FOREWORD

This conference was convened by the Lovelace Foundation as a means of bringing together people interested in the study of the biological effects of electromagnetic pulses (EMP). The conference was conducted on an informal basis during which participants were first given an opportunity to discuss early work that they have performed in the area of EMP. Following this review, the conference was opened to discussion of areas of interest and suggestions for future work in these areas.

The proceedings reported herein, which were taken from a recording of the sessions, have been edited as necessary for clarity and continuity.

CONFERENCE PARTICIPANTS

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INTRODUCTION AND EARLY WORK AT THE LOVELACE FOUNDATION*

F.G.Hirsch,M.D. and A.Bruner Ph.D.

Dr. Hirsch: There is probably no parallel to the arrogance that I am about to display, but inasmuch as the published proceedings of this meeting will be read by some who are unfamiliar with electromagnetic pulses (EMP), the session will open with a discourse on them delivered by a physician to an audience composed chiefly of engineers. Perhaps this is just as well since you are all invited to disabuse me of any mistakes in my concepts which will be forthwith revealed.

The two installations with which we have been working are the ALECS (Air Force-Los Alamos Electromagnetic Calibration Simulator) and ARES (Advanced Research Electromagnetic Simulator) operated by the Air Force Special Weapons Laboratory (see pp. 21 and 22). These are basically similar and differ chiefly in size and peak pulse power. Both have an aerial wire assembly resembling guitar strings separated from a grounded plate structure. The basic equivalent circuit is diagrammed in Figure 1. A condenser is charged by a van de Graaff generator to the desired voltage. The condenser is discharged into the aerial assembly creating a pulse of electromagnetic energy which travels down the apparatus in a manner which is essentially like that shown in Figure 2 and which has a waveform shown in a somewhat idealized form in Figure 3.

The ALECS pulser can be charged to a peak voltage of 1.5 megavolts and ARES to 3.0 megavolts. Electrical field densities of various strengths are obtained depending upon the location used between the overhead wires and the ground plane. Figure 4 shows the relationship between peak voltage and field density that pertained to the locations we used in our experiments. We obtained somewhat higher field strengths under ALECS than under ARES even though the peak voltage of the latter is twice that of the former. This is so because we worked at a spot on ALECS where the distance between the overhead wires and the ground plane was only 2.0 meters whereas this distance was 6.0 meters in the case of ARES.

It is important to understand that we are dealing with an electric field in this work and not with a current. The numbers involved are large and can be misinterpreted if the field concept is not clearly understood.

I found it helpful to equate these electric fields with those found in atmospherics. As we sit here today, we are in an electric field of about 200 volts per meter. When a thunderstorm is building up, field strengths of perhaps 20

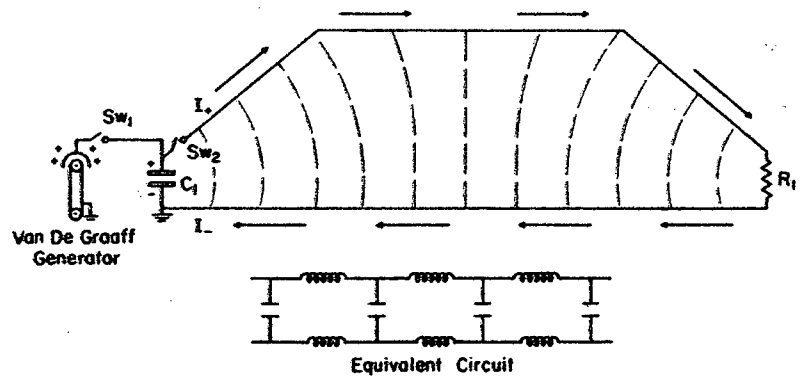
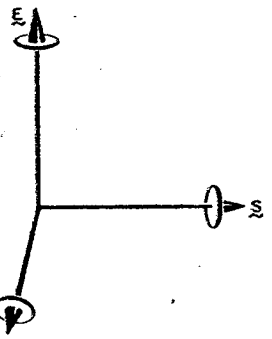


Figure 1. Equivalent Diagrammatic EMP Circuit.

*Early work supported by NIH Grant PH 05531.



Where: $\underset{\sim}{E}$ = electrical field intensity vector.
$\underset{\sim}{B}$ = magnetic flux intensity vector.
$\underset{\sim}{S}$ = "Poynting Vector" i.e., direction of energy flow.
$\underset{\sim}{E}$, $\underset{\sim}{B}$, & $\underset{\sim}{S}$ are mutually orthogonal i.e., $\underset{\sim}{E} \perp \underset{\sim}{B} \perp \underset{\sim}{S}$

Figure 2. Vector Diagram of EM Field at any Particular Instant in Time.

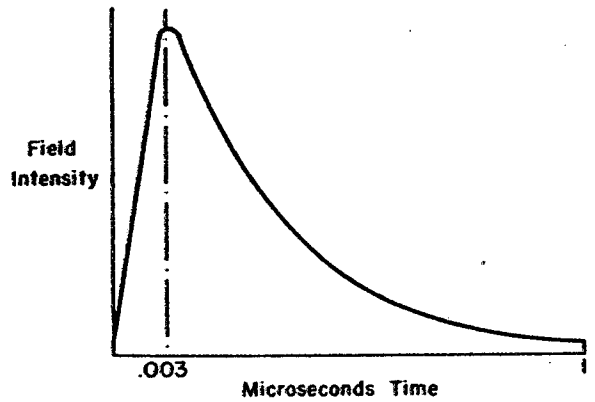


Figure 3. Typical EMP Waveform (Idealized).

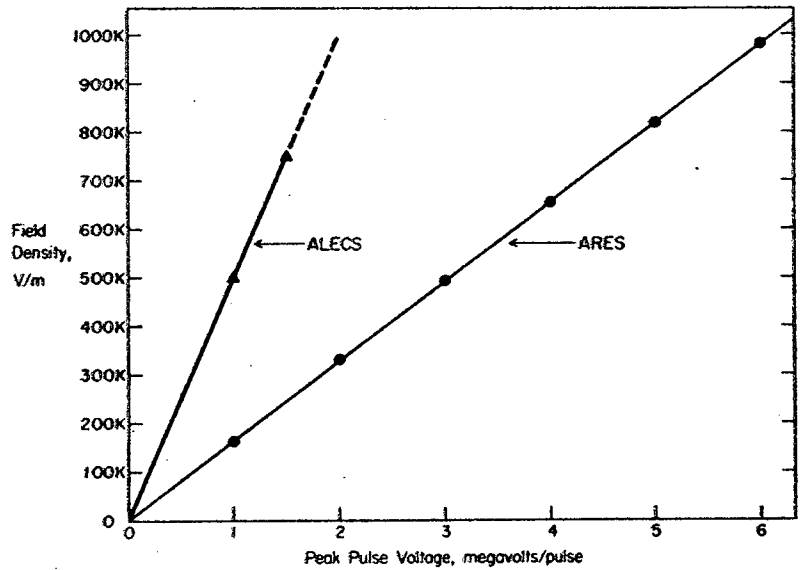


Figure 4. Field Density as a Function of Peak Pulse Voltage for ALECS and ARES.

kilovolts per meter exist under the storm cloud. When a lightning stroke occurs, a pulse of as much as 3.0 megavolts per meter is generated. Figure 5 shows several pulse shapes which have been postulated by various meteorologists. In general, these agree insofar as general configuration is concerned and their similarity to the pulse shape of the EMP generators is apparent.

In the vicinity of a thunderstorm, pulses of several hundred kilovolts per meter are common. Figure 6 shows a scaling curve which plots field strengths versus distance from a typical lightning stroke. The curve is a plot of Malan's equation:

$$\Delta Q = 2\pi\epsilon_o \left[\frac{h^2 + R^2}{\sin \arctan\left(\frac{h}{R}\right)}\right] \Delta E$$

where:

- ΔQ is the charge transfer (coulombs)
- ϵ_o is the dielectric constant of air
- h is height of thunder cloud (kilometers)
- R is the distance from the lightning stroke (kilometers)
- ΔE is the vertical field change (volts per meter)

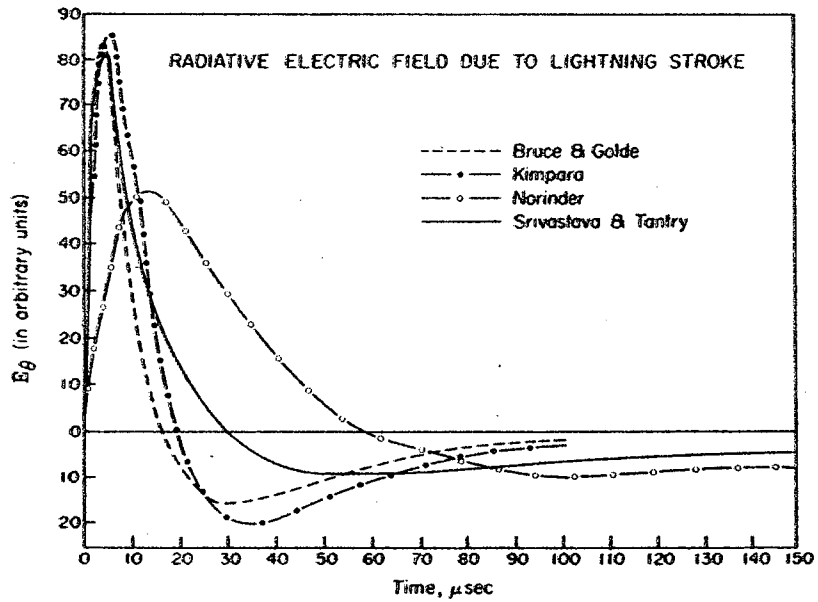


Figure 5. Radiative Electric Field Due to Lightning Stroke.

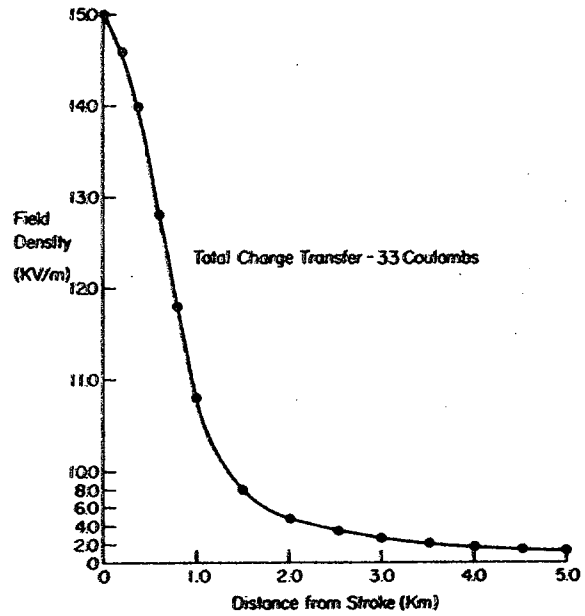


Figure 6. Electrical Field Density vs. Distance from Lightning Stroke.

One sees that for distances up to several kilometers substantial field strengths are generated by lightning strokes. Since we have all, at one time or another, been proximate to lightning strokes we have been in fields whose densities were several hundreds of kilovolts per meter without being aware of it.

There is no visual sign of the pulse when either of the pulsers is operated in the daytime. At night, one can see the corona similar to St. Elmo's Fire*. There is very little sound as well, all one hears is a sort of muffled crack like the sound of a small caliber firearm equipped with a silencer.

The first experiments that we conducted to determine the possible effects of EMP were performed on maze trained rats. Because of the apparent similarity between an EMP and the electrical field charges that accompany a lightning stroke, we elected to use a psychological approach for these initial tests. There are several reports in the literature which document the psychological disturbances experienced by people who were quite close to a lightning bolt but not actually hit by it. These people experienced a temporary confusion and a temporary difficulty in performing an acquired skill such as riding a bicycle, driving an automobile or flying an airplane.

For our tests, we used young adult female albino rats trained in a conventional maze having a configuration as shown in Figure 7. The motivation for learning was hunger. All of the animals had achieved a performance level where they would run through the maze in about three seconds without committing any errors.

After their training, the rats were taken out to the field site and required to perform under conditions which differed considerably from those that existed in the laboratory. Although the animals adjusted to this environmental change quite well, they never quite reached the performance times they had achieved in the laboratory. They did not, however, commit any errors.

*The cover of the proceedings shows a night photograph.

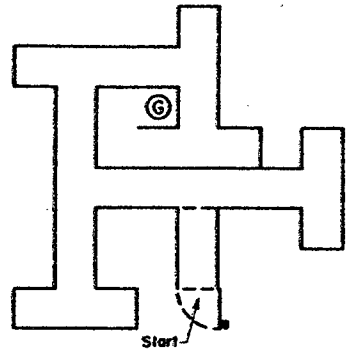


Figure 7. Layout of Maze Used for Rat EMP Exposures.

The maze was equipped with a starting box that had a sliding door which could be opened by a rubber band when a restraining peg was pulled by activating a solenoid. In this manner, a start of a maze run could be coordinated with a pulse. In practice, the animals were placed in the starting box and when the generator was ready to pulse, an observer would open the starting gate and give a hand signal to the generator operator who would initiate a pulse. The maze was situated near the insertion of the ALECS pulser and placed on a box which raised the animal to a midpoint where the antenna was separated from the ground plane by 2.0 meters. At this point, a 1.0 megavolt pulse gave a field density of 600 kilovolts per meter.

Each animal was required to run the maze after receiving a pulse. They received three consecutive pulses separated from each other by the 10- to 15-minute interval required to recycle the pulser.

In addition to the trained animal in the maze, another rat was placed in a plastic container which was electrostatically shielded. This animal was observed for evidence of a "startle" response coincident with the pulse.

A total of seven animals were exposed and all behaved in the same manner. In brief, there was manifest a disruption of the maze running ability characterized by a prolongation of running time, a hesitancy at decision-making points and an ultimate refusal to run after several pulses. This disruption, however, was temporary since the animals performed at their pre-exposure levels after a half hour or so. We observed, then, evidence of a temporary cumulative effect. The animals in the maze all showed a "startle effect" at the instant of pulsing which was not observed in the animals contained in the shielded enclosure. Table 1 tabulates the results of our experience with two of the seven animals.

Therefore, in view of a temporary disturbance in the ability of all rats to perform a recently learned task, we felt that there could be an EMP effect.

These experiments have been fully described in a paper published in the "International Journal of Biometeorology" (Vol. 12/3, 263-270, 1968).

The next study was a simple exposure of a large (75 lb.) stump-tailed macaque monkey confined in a wooden cage and exposed to the pulse from the ARES pulser. The animal was untrained and uninstrumented on these exposures. We simply observed him for obvious departures from normal behavior. This monkey has been used many times in various experiments ranging from receiving injections of radioisotopes to being exposed to shock waves both in a shock tube and on a high-explosive pad. He is quite old, has been in our animal colony for years and possesses a number of behavior eccentricities which are well known to all of us.

He received eight pulses spaced about 15 minutes apart at field strengths from 300 to 600 kilovolts per meter. He manifested no departure from his normal behavior and showed no obvious startle or stiffening when the pulse was generated. He was thoroughly bored by the whole procedure, as were we by the end of the day.

Table 1

SUMMARY OF MAZE RUNS

Date	Animal No.	Preexposure Runs		Pulse No.	Postexposure Runs			Remarks
		Time	Errors		Interval	Time	Errors	
11-16-67	14	3	0					
		3	0					
		3	0					
				1	immed.	16	0	"Startle"
				2	immed.	5	0	"Startle"
				3	immed.	NC	NC	"Froze" at starting gate.
					30 min	6	1	Frequent hesitation at decision points.
					1 day	4	0	
					2 days	4	0	
					3 days	5	0	
					4 days	4	0	
					5 days	3	0	
11-17-67	7	5	0					
		7	1					
		4	0					
				1	immed.	NC	NC	"Startle". Made wrong turn out of box. Returned to box.
				2	immed.	NC	NC	Did not leave box. Turned 180° and faced entry door.
				3	immed.	NC	NC	"Startle". Did not leave box.
					30 min	12	0	Hesitant at decision points and seemed "cautious".
					1 day	4		
					2 days	4		
					3 days	3		
					4 days	6		
					5 days	5		

Note: All times in seconds.

In one of our latest experiments, we exposed an operantly conditioned rhesus monkey to the pulse from ARES. We chose the positive pulse mode for no particular reason other than ALECS had been pulsed positively in our rat experiments. We were fortunate to have motion picture coverage of these experiments which was provided by EG&G. The film which you will see, unedited, really speaks for itself. I will ask Dr. Bruner to give you a commentary as the film is run.

Dr. Bruner: We exposed the operantly trained rhesus monkey, an adolescent of about 9 pounds, using the same cage that we had used for the stump-tailed monkey. In the movie which you will see, not all of the pulses are shown.

> The color movie, approximately 15 minutes long, presented the performance of a rhesus (Macaca mulata) monkey during a series of nine EMP's: five at 300 KV/m, two at 450 KV/m and two at 600 KV/m. The monkey, trained to avoid a shock by pressing one of five keys appropriately in response to a tone (200 to 20,000 Hz) or a lighted key, exhibited no changes in his test performance or other behavior as a result of the EMP. He continued to perform with virtually no errors during the series of pulses. The only indication of receipt of the pulse was a mild startle reaction which might have represented simply his readiness to lurch toward the response panel at any stimulus. The animal behaved and ate normally when placed back in his living cage.
>
> During his narration of the movie, Dr. Bruner pointed out that a metal collar, which was part of the shock electrode used in the training of the animal, was removed during the EMP so that it would not act as an antenna for the pulse. The animal, being highly overtrained, continued to respond appropriately even without shock reinforcement. In subsequent testing on another day, the floor of the cage was covered with wire mesh and connected to the pulser ground plane with heavy battery cables, providing good contact with the monkey's feet. There were no other connections to the animal. Still, he did not show any effects whatsoever of repeated EMP exposures.

Dr. Bruner: In another experiment, we simultaneously exposed four Dalmation dogs to several EMP's on a single day. The dogs were held in a wooden box and separated by partitions so that each had enough room to stand. Two of the dogs were grounded through a wire mesh floor connected to the pulser ground plane. The other two dogs were isolated from ground by the wooden floor of the cage. None of the dogs were connected to any other electrical circuits. We pulsed them 8 times, building up to a level of 600 kilovolts per meter. We performed pre- and post-exposure SMA-12 blood analyses on all four dogs. Neither Dr. Hirsch, myself nor the veterinarian could see any difference in the pre- versus post-exposure values. We had our biostatistical expert take a look at the blood data and he thought that there were a couple of them that showed a significant difference from pre- to post-exposure; however, since there was no consistency in these, we were inclined to regard all the data as showing no significant change. There was no particular reason why we chose the parameters shown in Table 2. It is very simple to do a batch of biochemical determinations on the automatic SMA-12 which is set up to run these various modalities for clinical purposes. They do, however, cover a broad spectrum of the biochemical activity in the organism. I would expect that if anything were to show a significant change it would be the lactic dehydrogenase, the alkaline phosphatase or the SGOT; none of these, however, showed any significant change either way. So this is about where we have gotten experimentally.

Table 2

Blood Analyses of Dogs Exposed to Electromagnetic Pulses of 600 KV/M

		SMA-12												HEMATOLOGY						
Dog Number	Date	Cholesterol	Calcium	Phosphorus	Bilirubin	Albumin	Total Protein	Uric Acid	Urea Nitrogen	Glucose	Lactic Dehydrogenase	Alkaline Phosphatase	SGOT	WBC	HCT	HGB	RBC	MCV	MCH	MCHC
Ungrounded Dog No. 1	6-15-70	196	10.4	5.7	0.4	2.7	6.3	2.1	33.5	84	101	11.8	44	8.3	42.9	16.2	6.9	64.4	24.0	67.3
	6-22-70	209	7.3	5.9	0.4	2.8	6.3	1.1	29.0	64	53	10.3	37	6.3	37.9	14.8	6.4	62.3	23.7	38.1
	6-30-70	205	8.3	4.8	0.3	2.9	6.5	1.4	29.0	93	107	9.0	42							
	7-1-70	220	8.0	5.9	0.3	2.7	6.7	2.2	29.0	65	65	9.5	36							
Ungrounded Dog No. 2	6-15-70	179	9.9	4.9	0.5	2.7	6.2	1.7	36.0	73	124	11.0	30	13.4	44.4	16.9		66.9	25.1	37.8
	6-22-70	186	7.5	5.1	0.4	2.7	6.0	1.4	33.0	60	64	9.9	27	12.0	45.0	16.4	7.1	66.5	23.9	36.0
	6-30-70	170	8.6	4.6	0.3	2.6	6.1	1.9	33.0	97	119	9.0	32							
	7-1-70	163	7.4	4.0	0.4	2.5	6.0	1.6	36.0	68	61	9.5	26							
Grounded Dog No. 1	6-15-70	173	10.4	6.2	0.7	3.1	5.4	1.6	27.0	56	161	16.2	37	19.1	46.3	17.7		68.0	25.9	37.9
	6-22-70	182	7.2	5.6	0.6	3.2	5.5	1.5	35.0	64	89	15.8	27	13.5	43.0	16.2		68.1	25.5	37.5
	6-30-70	195	8.3	4.9	0.2	3.4	6.1	1.6	31.0	90	156	14.3	36							
	7-1-70	191	7.3	4.6	0.7	3.6	6.2	1.6	35.0	95	79	14.8	24							
Grounded Dog No. 2	6-15-70	178	10.9	7.6	0.61	3.3	5.6	1.5	31.0	55	62	16.1	33	11.0	48.1	17.0		70.5	24.9	35.1
	6-22-70	210	7.0	6.3	1.1	3.3	6.1	1.2	30.0	63	115	15.0	33	11.8	44.9	16.4		67.5	24.8	36.7
	6-30-70	204	8.9	5.3	0.3	3.1	6.0	1.5	20.0	100	163	14.2	38							
	7-1-70	200	7.6	6.1	0.6	3.3	5.9	1.5	24.0	79	72	15.7	27							

Dr. Hirsch: What it all adds up to, at least as far as I am concerned, is that we have found something which seemed pretty forthright in the rat, nothing of the same sort in the primate and nothing of significance in the biochemical determinations that were run on the dogs. Captain Evans has some data about human exposures from the Air Force Dipole Facility which he will tell you about. After he finishes, we will throw this session open to general roundtable discussion and try to answer questions or bring out things that are of interest to you. In reference to the Dipole Facility, I think that in order to make it clear, we will ask Lt. Col. Portasik to tell us something about it before Captain Evans presents his data.

U.S. AIR FORCE DIPOLE FACILITY

Lt.Col. J.Portasik,USAF and Capt.K.Evans,USAF,MC

Lt.Col. Portasik: I don't know how interested you are in it, but to me it is not what causes the field, but the field itself. The Dipole Facility is exactly what it says. It's nothing more than a long pipe separated in the middle by a spark gap. The pipe is approximately 320 feet long and about 40 feet above ground level. In normal operation, we charge up one side to 100 KV plus and the other side to 100 KV minus, at which time the spark gap will arc and create what we hope will be a plane wave. At 5 feet above the ground and directly underneath the dipole, this field has been measured at a peak value of approximately 3500 volts per meter. The wave shape is roughly as shown in Figure 8 and will build up to a peak in somewhere around 6 nanoseconds. So this is the type of field people are working around all the time. You can make a rough calculation as to what the field levels are some place besides the working point, but these are not really accurate because you have to start worrying about the far-field effects. However, if you set the decay rate at approximately 1/R, you're somewhere in the ball park. About 100 feet out, with the level we're operating at, the field strength is roughly 700 volts per meter.

A lot of us walk in that region all the time. It's funny how we will have visitors come out and the facility will be pulsing away. The people don't really know what's going on and they're nice and calm. But when we start talking about the field levels to which they are being subjected and say "Well, here we are in about 1000 volts per meter, then all of a sudden the "tingling" starts.

Do you have any questions concerning this particular environment? The difference between this facility and either the ARES or ALECS facility is that they are built as more or less of a parallel plate type transmission where you can confine the energy. The dipole is a radiator which is omnidirectional, so to speak.

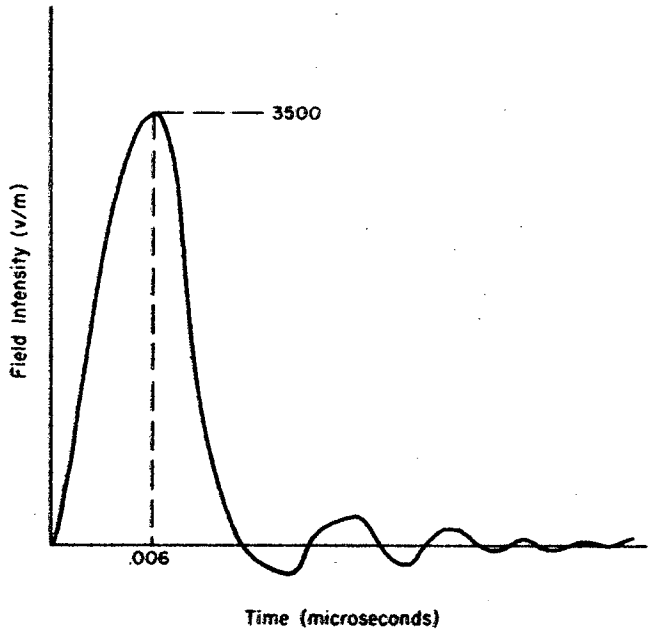


Figure 8. Typical EMP from Dipole

Question: What is your repetition rate there?

Lt.Col. Portasik: The dipole facility repetition rate is about 12 pulses per second whereas ARES can be recycled only about once every 3 minutes.

Question: I have heard a rumor that people working in an EMP environment have been having babies all of the same sex. Is there anything to this?

Lt.Col. Portasik: I think that this phenomenon has just about had it, because after 12 in a row where the people had all girls, the 13th one was a boy.

Dr. Hirsch: Well, at the same time, over at one of our local elementary schools, every teacher that had a baby had a child of the same sex. They finally broke that string at 17. I can't equate dipoles and third grade teachers very well.

Lt.Col. Portasik: These statistics bother me too. I used to teach mathematics at the Air Force Academy a long time ago and I was teaching a real high level course in algebra. We got into statistics and probability so I thought I would play it smart and show these kids how probability works out. So I took a penny and said, "Now you see, flip a penny and the probability of heads on each flip is 1 to 2. Now let's flip this thing a bunch of times and see what happens." Out of all the times that it shouldn't happen, I flipped tails 10 times in a row, on the first 10 flips. After the tenth time, the class broke up and they said they wouldn't believe in probability any more.

One thing that I am going to say is that since we operate the dipole at high levels we have established safety distances where people cannot enter. We did this strictly as an arbitrary precautionary thing. Until we get some valid data and some hard and fast figures to operate with, we'll continue to use what we have now as our safety parameters.

Question: What was that figure?

Lt.Col. Portasik: When we're operating at high levels, we use a 200-foot radius as a safety area.

Capt. Evans: We have a group of people who work with EMP in the Dipole Facility. They have worked in this facility for intervals of two to three months, some of them up to almost two years, eight hours a day for five days a week at a field strength of 1000 to 10,000 volts per meter. These are rapid repetitive pulses, as I understand, in terms of nanoseconds. As we had no opportunity to get any pre-exposure control data for these people, we set up a study where we called in about 15 or 20 of them. We performed CBC, PBI, blood pressure and pulse, EKG's and talked to them about their subjective responses. We compared their responses with those we would consider normal for an average population. We did a white count, differential, hematocrit, reticulocyte and platelet count. We obtained a urinalysis with determinations of specific gravity, sediment study, albumin and sugar. We also drew a PBI (Protein Bound Iodine). All of the values on each of these individuals fell within the normal range. The EKG's were all within normal limits as far as rate, rhythm, and timing of the PR interval and QRS complex. Essentially, we found no changes in any of our physiologic parameters that we could consider outside normal limits.

The only changes we found were in talking to these individuals subjectively. About four of them reported easy fatigability since they had been at the facility. Most of the individuals, however, had absolutely no symptoms, no problems or complications of any kind. We drew up a list of specific things to ask them, such as weight changes, births in the family, changes in their sexual drive, concentration span, increased frequency of colds or infections, medical ailments, aching joints, headaches, changes in sleep patterns, any visual changes, and changes in sense of well being during leaves or vacations. Two or three individuals had gone on leave during the period of time they had been working at the facility and noticed no change during the time they were on leave and after they came back into the facility. We asked about palpitations, stammering, general irritability or any other changes that they had noted and whether they could attribute them to working in the area. The only change we did find that we were able to contribute any significance to at all was the mild, easy fatigability. There were two instances of individuals who worked for approximately 8 hours extremely close to the source, possibly about 15 feet. These two individuals reported (on the same day) extreme fatigability, extreme irritability, real arthralgia, aching of the joints when they moved, mild frontal headaches, they snapped at everyone and were extremely tired that evening. They both went home, got eight hours sleep and felt perfectly well the next morning as far as we know. We did not see these individuals at the time that this occurred. It was about a month later when we first saw them but neither of them had noted any residual changes after the one day. As I said, these two individuals were working approximately 15 feet from the source on an electrical problem not related to the dipole.

Question: Any idea of approximately what they received?

Capt. Evans: It should have been somewhere around 3500 volts per meter. One of the individuals did note that at this level while they were working that when he touched some metal object, he got a very mild shock on one or two occasions. Whether these were related to electrical shock or to EMP, we were unable to say. These were the only significant things that we were able to determine in talking with the 18 to 20 people and drawing these physiologic parameters. So far as we are concerned, there were absolutely no changes except for the two individuals whom I'd say were working at extremely high field strengths for a long period of time.

Are there any questions about anything? We had intended and still intend to attempt to do EKG's within the field, but unfortunately we are a little short in manpower in the dispensary and have been unable to get this done as yet. We intend to go over next week and run some EKG's in the field if our machine will function in the electric field, and I assume it will. We will see if there are any changes on EKG's electrical conduction, etc., while an individual is being exposed.

Question: Were those two people exposed that close to the source for just one day or for several consecutive days?

Capt. Evans: For just one day. Most of this time they were actually off the ground on a ladder and closer to the facility. As I understand it, the dipole is about 40 feet off the ground. The rest of their working days had been spent basically on the ground about 40 feet or so from the source.

Question: Were they accustomed to that sort of labor or was that an unusual type of activity?

Capt. Evans: As I understand it, it was not an unusual type of activity. They are in the maintenance end of the facility and do similar type of work. However, the thing that impressed me was that they both mentioned the severe arthralgia, severe irritability, snapping at their wives and everyone else. After discussing this with them, I found they had not discussed this with each other until after the incident occurred. After they got off work, they were a little tired and they apparently got more tired as the evening wore on and some of these symptoms became progressively worse; however, by the next morning, they felt better.

Question: What is your estimate of the exposure of these people who worked for two months or up to two years in the field? Do you have any idea of what it might be?

Capt. Evans: Total exposure? No, sir. The field strength is about 1000 to 10,000 volts per meter and these are rapid repetitive pulses.

Question: How many pulses per second do you have?

Capt. Evans: Twelve pulses per second.

Question: But you actually don't know what the exposure was to these people?

Capt. Evans: No, sir. This is basically all we have been able to derive from this so far. We are essentially dependent on variable changes and so far there have been very few changes, if any, that we were able to find out or at least measure by these parameters which I have discussed.

Mr. Shopenn: I know personally of one individual who has worked in EMP fields now for about eight years, and I've known him pretty much of the time. He hasn't changed in any way I have observed.

OPEN DISCUSSION

Dr. Hirsch: I just want to emphasize the difference in the exposure of those two men and those we've done experimentally. The outputs of the two pulsers are quite different. The men got about 12 pulses per second out of the dipole with a maximum output of 11 kilovolts per meter, whereas with the animals, the pulse rate was about one every 10 minutes and the field strengths were enormously greater, 600 or 700 kilovolts per meter. We're not talking about the same magnitudes of exposure.

Dr. Bruner: We have been standing about 20 or 30 feet from the monkey at ARES and getting about 15 kilovolts per meter. Yesterday, I held onto the ground plane screen and didn't feel a thing.

Dr. Hirsch: Congratulations, nothing like throwing yourself into research. On that rat work, as I said, we activated the starting gate with a push-button switch with a wire about 70 feet long. It was rubber covered zip cord just like you use for an extension cord. They warned me to push the button and then drop it. On one occasion, I forgot to drop it and it gave me a pretty good jolt in the thumb. Now these other two men who were working under the dipole noticed mild shocks when they touched metal. But on the other hand, when we stood on the ground plane, there was no evidence of any shocks. When you are training monkeys with shock you give them a pretty good voltage, 200 volts at about 5 milliamperes. In comparison, the shock you get from a pick-up like the switch button or by touching a metal object is much briefer and at much less voltage. The monkey is used to getting 200 volts at 5 mils if he doesn't perform or makes an error, so he is probably not going to pay much attention to this rather weak shock which might come in through the ground, if indeed one did. These are some differences in the configurations and techniques of exposure which might have some sort of significance.

Capt. Schwartz: Now there are two questions that I have. First, about the monkey's sensitivity to any disruptive phenomena. As was mentioned, he was an extremely over-trained monkey. I was wondering what, in terms of known disruptive stimuli, drugs and other stimuli are known to disrupt them? How much do these monkeys require, that is, what I am really wondering about, what is the sensitivity of these monkeys to these things. He apparently has had a very extensive training at a very low center of response. Can these monkeys be disrupted by noxious agents easily?

Dr. Hirsch: Not easily. I have to fall back on some other experience that involved the exposure of primates to ionizing radiations. These animals even though they were quite sick from radiation sickness, would still try to manage to do their thing. This was true of a bunch of trained rats we had at the proving grounds a long time ago. These animals had been trained in a jumping technique. They had radiation sickness to a point where they could hardly stand up and yet they would try to do it. So I think that once you plant this training, it's pretty hard to shake out.

Capt. Schwartz: So they're not sensitive in terms of threshold or dose?

Dr. Bruner: Your question implies that we were trying to find out if they could detect the pulse and this wasn't the purpose at all. It obviously didn't cause anything dramatic. Now we weren't trying to determine their threshold of disruption from the EMP. If you walked near them, called or clapped, they would stop and look at you. Rather, we were trying to determine whether there were any obvious effects of the high density EMP.

Capt. Schwartz: My other question. I was just noticing the dog study. I noticed that in the dogs in the calcium, the original on the 15th, the baseline of each dog was higher. I noticed that none of them ever recessed. When you take the end one and compare it with the beginning one, at least according to the laboratories that I am familiar with, there is quite a difference. What do you make of that?

Dr. Hirsch: Nothing as yet. We are still trying to make some sense out of it.

Dr. Bruner: I am doubtful about our baseline measurement of calcium. The first four pre-tests for each dog were high. The second four pre-tests for each dog were low. These were both baseline pre-treatment measurements. So I am kind of skeptical about our measurement by the SMA-12. You see that the baseline measurements varied over a wide range which the post-test values did not exceed.

Question: Isn't this evidence of poor reproducibility?

Dr. Hirsch: No, in clinical practice the reproducibility on our laboratory work is of a high order. These animals were not brought to basal levels by fasting. We will probably have to have substantially more determinations before we begin to see any trends or conclude there aren't any.

Dr. Bruner: The dogs were not fasted and the blood samples were drawn after feeding. There were a lot of such variables out of our control.

Dr. Williams: I think that the results of the data are encouraging, but I don't know of one shred of the data that indicates there is no damage that might be cumulative. All this is behavioral. I would ask if there have been any studies to see if there are any chromosomal changes in animals before and after exposure. If anybody has done any extensive investigation at the electron microscope level to see if there have been any changes in the microstructure in the cells, especially nerve cells where you might expect damage to begin if it is going to be an effect on the central nervous system. There could be a lot of damage to the human and monkey's central nervous system that would never manifest itself in terms of behavior and the fact that this can occur is very well known. If somebody gets sufficiently drunk there is cell damage in the brain. After he sobers up, however, he is apparently normal, but nevertheless there has been some irreversible cell damage in the brain. I think there is a legitimate question as to whether or not this occurs under the influence of EMP. I'm not saying there is, but I'm saying the question is not even being looked into.

Dr. Hirsch: It has been proposed, but it hasn't been funded. Therefore, it hasn't been done.

Dr. Williams: All right. One other area that I happen to have a passing interest in happens to do with the heart and the pacemaker. I would ask if anybody has done any study to see if EMP blocks the pacemaker.

Dr. Hirsch: No. We have been funding this work from our own sources at a very modest level and in order to do a number of things that should be done we will require some backing, since what you are suggesting will require expensive and sophisticated experimentation.

Dr. Bartl: If you were responsible for a group of people working in that operation or around that operation. At this time, what safety criteria would you use--100 or 1000 volts per meter, or what?

Dr. Hirsch: Well, I can just give you my own personal opinion. I think that it is completely fallacious to extrapolate the microwave criteria into this area. When you look at the situation realistically, certainly I would have no hesitancy about working around 10-15 kilovolts per meter or getting pulsed occasionally over a number of days at power densities of 100 kilovolts per meter. I see some chance that there is a cumulative chronic effect at lower levels but, on the basis of what we know from human exposures and what I can read into the animal studies, I downgrade the notion that there is any acute hazard. When you are standing out in the open near a thunderhead that's developing in a thunderstorm, you are in a field of 20 kilovolts or better at the time. This phenomenon is pretty close to people who have been doing high-voltage transmission line work. They have been getting similar results. I have read a couple of short articles which said that they could stand directly under the transmission lines and get a tingling sensation. There was one case where they were feeling more tired than usual but of course there were other things they had been working on so it's hard to tell if the field would be connected with their symptoms.

Dr. Williams: I'd like to point out though that the effects that you are talking about are at lower frequencies, much lower than EMP. In terms of the thunderstorm, the body is essentially part of the ground plane until the flash takes place. I just want to make a comment before we leave this. I wonder if anybody has made a measurement of the depth of the penetration to the central nervous system from the pulse?

Dr. Hirsch: No.

Dr. Williams: One of the reasons for tossing that out was that another person with whom I am acquainted, is trying to develop a technique and also use it for his dissertation if he can, that would allow you to measure the transient pulse.

Dr. Hirsch: Fred (Dr. Bruner), you're probably more familiar with that sort of thing than I am.

Dr. Bruner: I think that it turns out that surface conduction or "skin effect" limits the degree of penetration of high frequencies to or near the surface of the body, but the actual measurements have not been made in this case.

Dr. Hirsch: In general, the higher the frequency, the less penetrable the energy.

Dr. Bruner: I think that in our present situation, we could monitor EEG if we implanted electrodes and connected them into the recording circuit shortly after the pulse to see if

there were brain wave changes. I think we could also measure the current strength of the portion of the pulse that penetrated the brain tissue.

Comment: I get the impression that everybody's looking for immediate effects. I have done some translations in Russian. Some don't seem to put too much faith in their work. They have reported cases of changes in the central nervous system that have been recorded, but it has taken anywhere from 5 to 15 years for these to show up and I think that everybody right now is looking for immediate effects. From what I've translated, they have shown definite changes in the area of the central nervous system over a long period of time.

Dr. Hirsch: One thing, when you're talking about a long period of time, it's pretty difficult to say that one particular thing caused a change in the nervous system. A lot of things could have been responsible alone or in combination. I've read most of the Russian stuff myself. I've found that their data is good to the extent of what they have found but they cannot directly pinpoint it to a specific effect.

It's certainly true that when you're studying the effects over a number of years, it's impossible to eliminate all of the noxious things that have happened to an individual. you're kind of in the same boat as when you're confronted with a fellow who cut himself on a circular saw and you're to say which tooth did it.

Dr. Williams: I still think that things that occur over a long period of time don't accumulate in a vacuum. They reside someplace, occurring in some cell structure. This is my suggestion: measure the electric field intensity inside the nerve tissue, look for small changes to provide answers for guys that work for EG&G who will have all girl babies and look for intracellular changes. Electrical energy appears to break down building blocks and if there are no changes there, I don't think changes will occur.

Dr. Bruner: These are the same questions that we have been discussing among ourselves here and I want to return to the question as to whether we felt that we were doing the best kind of experiments, and the answer is, we do not. We are operating essentially without a budget. This means that we are having to use the pulses that were generated for other purposes. We were just sort of an annoyance to the people at ARES, --- "What are those funny guys with monkeys up to." This is all that we have managed to do right now. If we were to continue, it would be primarily chronic, long-term studies. We feel that the single shot, high density stuff is harmless and it may not really be of too much interest to those of you concerned with the safety of personnel working in the fields. You are more concerned with the 8 hours a day, repeated exposures at low levels. So what we're thinking about is that we'd like to test some animals living a long time under the pulser. We would include several different species, some of whom reproduce rather quickly so we could look for changes in offspring and perform chromosomal and biochemical studies on them. We could have some monkeys and also we could do some more behavioral work. We do think that the thing that has to be done next, is chronic, long-term exposures.

Dr. Hirsch: I would like to ask Dr. Bartl to repeat some of the questions that he asked me a few minutes ago and see if we can bring up something appropriate to look for in the way of examining people that are exposed.

Dr. Bartl: Again, a hypothetical question. What would be a reasonable exposure limit to people exposed for 8 hours to a 5 kilovolts per meter pulse every 5 minutes. This is the essential question I have, since it is what we are faced with.

Dr. Hirsch: Anybody got any ideas on that one?

Dr. Bartl: At the moment, we have established a criteria of 400 volts per meter.

Capt. Schwartz: We have postulated that there is a different sensitivity for different people. I think that it is very difficult to make a justifiable statement on that point. We were just speaking about two minutes ago about the effect of microwaves on a few cases of people with pacemakers who walked past a microwave oven and immediately keeled over. I think that in considering the sensitivity of an individual with an electrical apparatus in his body to a field that this individual should be restricted to a much lower level than an individual without one. I think it would be a variable thing depending on circumstances.

Dr. Hirsch: What would be a significant thing to follow on these people--EEG, EKG, blood chemistry, or what?

Capt. Evans: We have practically no published data really to be able to state that PBI alterations are the result of exposure to radar. When I reviewed the literature about a month ago, there were no parameters that could possibly be used in our laboratory because most of the changes recorded, the ones that we could definitely investigate weren't the ones the Russians used. They felt, especially with radar work, that they had uncovered some changes as a result of working near these particular fields. Vagueness has been our only finding so far. The blood counts that we've followed showed no significant changes and in your dog studies there seems to be no significant difference. I find that EKG's look as if there are no changes when a person is removed from the field. We have not gotten EKG's inside the field yet since we feel the interference will in itself produce an artifact in the tracings.

Dr. Bartl: Would there be difficulties in obtaining a continuous EKG recording over 8 hours for several days which was synchronized with the pulse?

Capt. Evans: This would be interesting. What we hope to do in the next week or so is to take an EKG over to the dipole and see if we can measure the EKG in the field, or see if there is too much interference on our lead wire, so that we can't measure it.

Comment: You'll never see it. The machine will be wiped out.

Capt. Evans: That's what we're wondering. We're going to try this next week. We don't think we can get a record but we're going to try anyway.

Dr. Hirsch: As far as that's concerned, I think maybe there's just a little picture of comfort. We got some false triggering but no extensive damage to our electronic equipment using a shielded cable. I don't think it will scrub out your equipment quite as easily as you're worried about. Of course, a fellow doesn't like to take an expensive piece of electronics out and wreck it. However, we haven't tried to measure any weak, bioelectric phenomena during the pulse, as yet.

After a break, the discussion among the participants revolved to the extent that identification of individual speakers was impracticable. The following is a summary of the remainder of the meeting as prepared by Dr. Hirsch from the transcription.

A discussion took place concerning the possible use of the electroencephalogram as a monitoring tool. The following questions were raised and the consensual answer is given.

1. Will the pulse cause artifacts which will be seen in EEG tracings, and which will really not be indicative of a physiologic effect? Will computer analysis be necessary?
   This is certainly a possibility but such artifacts should appear when the machine was running under a dummy load and thus be identified. We doubt the need for computer EEG analysis but this could be readily accomplished.

2. Is there a direct electrical hazard associated with having a patient hooked up to an electronic device which is subjected to an EMP?
   A preliminary study using an experimental animal should certainly be done prior to using a human subject, particularly with deeply implanted electrodes, or electrodes on or near the heart. This has not even been done using a conventional EEG or EKG configuration. My recollection is that the monkey referred to, received only electroanesthesia currents applied directly to his tissue. No EMP's were administered. I asked the man about this.

3. Would the EEG be likely to be useful in monitoring or evaluating industrial exposures?
   It is unlikely that it would be so used. As a research tool the technique might well yield useful data, but the practical difficulties involved fairly well rule it out as being useful in an industrial milieu.

The discussion then turned to the matter of choosing the parameters which should be included in an examination schedule for personnel subjected to chronic exposures to EMP.

It seems that the most useful indication would be to look for indices of change in the general state of well-being in the exposed population. Such things as weight changes, appetite, sleep habits, libido, mood, etc., might be useful and could properly be expected to be revealed by a health questionnaire of some type. It might be useful to obtain blood counts, urinalyses, and other biochemical tests which would have implications for general physical condition.

It was felt that procedures directed at functions that are known to be electrically sensitive such as the EKG and EEG might well be useful.

It was further the opinion of some that a battery of psychological tests such as reaction time measurements, mental arithmetic tests, etc., might help to get some insight into changes in mentation.

At the same time, there was expressed a feeling rather generally amongst the participants that since what was being looked for was so poorly identified that to formulate a really meaningful set of examinations was indeed difficult.

It was pointed out that many things have an impact on general health, alertness, and mood other than what an individual receives in his occupation. There is also some hazard in being so over-cautious that anxiety is implanted in the employed population as a result of too many examinations or obvious concern. Then too, the manner in which questions are asked will often color the answers given.

It was felt important too that considerable effort be expended in getting and maintaining records of exposure data. If a chronic effect exists, it will surely be dose dependent. The absence of any sort of dosimeter is a real handicap in this connection, and the prospect of someone developing such a device which can be worn while in an EMP environment is not bright.

The suggestion was then made that as many of the attendees as possible make an attempt to formulate a surveillance protocol and submit them to a central place where they could be collated and submitted for a general critique by others. In this way, a program which makes sense would emerge, and become a sort of guideline that everyone could follow with some degree of confidence.

The next item discussed was the matter of permissible exposure levels. A need for some sort of guideline values of permissible exposures to EMP was expressed by several of those in attendance, all of whom were occupational health physicians, safety engineers, or health physicists. In other words, those who have responsibilities for health protection of people who are currently working in an EMP environment.

The situation of the day-to-day working level is another matter. We have evidence from Dr. Evans' investigations in EMP workers that these people show no ill effect attributable to their working environment and some of them have been in their present jobs for several years. However, this aspect of the problem has not been looked into anywhere near to an extent adequate to permit any conclusions. It does seem that a working level of 500 volts per meter continuous dose which is used as a guideline by one of the organizations represented, is quite a bit lower than it need be, and can in time be restrictive as the ability to produce EM pulsers becomes larger and produces higher fields. It would seem that this level could be raised by at least ten-fold without apprehension.

Admittedly, the presently available data, and experience with human exposures are meagre, and do not permit the establishment of any firm maximum permissible exposure values for either the acute case or the chronic daily exposure situation. It was felt to be useful and desirable to consider the matter at some length.

Insofar as the single pulse is concerned we have evidence that primates can tolerate a pulse which places them in a field as high as 600 kilovolts per meter without evidence of ill effect. During the performance of the maze experiments described earlier, the human observer was stationed where the field strength was calculated to be in excess of 100 kilovolts per meter. Measurements taken at locations near the pulsers in Albuquerque have shown values from between 11 kilovolts per meter and 60 kilovolts per meter. People have been regularly in these locations when the devices have been pulsed without any known deleterious effect. Finally, the extrapolation of the electric fields associated with thunderstorms to the EMP situation indicates that single very high density pulses produce no effect. So it seems that one can say beyond peradventure that a single pulse of 11 kilovolts per meter can be tolerated with apparent impunity. Such evidence as exists suggests that the single pulse tolerance is really several orders of magnitude greater than this.

It must be emphasized, however, that the health physicist and occupational health physician need the data from further studies in order to be sure of their ground. Even though such studies seem likely to yield largely negative results they should be done so that those placed in positions of responsibility on the "front line" will have a body of knowledge to assist them.

In order for such studies to be done, support in the way of funding will be required and cooperation established between investigators and agencies operating pulsers. Research into the chronic effects need not be elaborate or expensive in order to be meaningful and useful; however, until this is done, nothing more than conjecture will be available for those who must answer questions, establish guidelines, and make decisions which may have far reaching legal and physiological ramifications.

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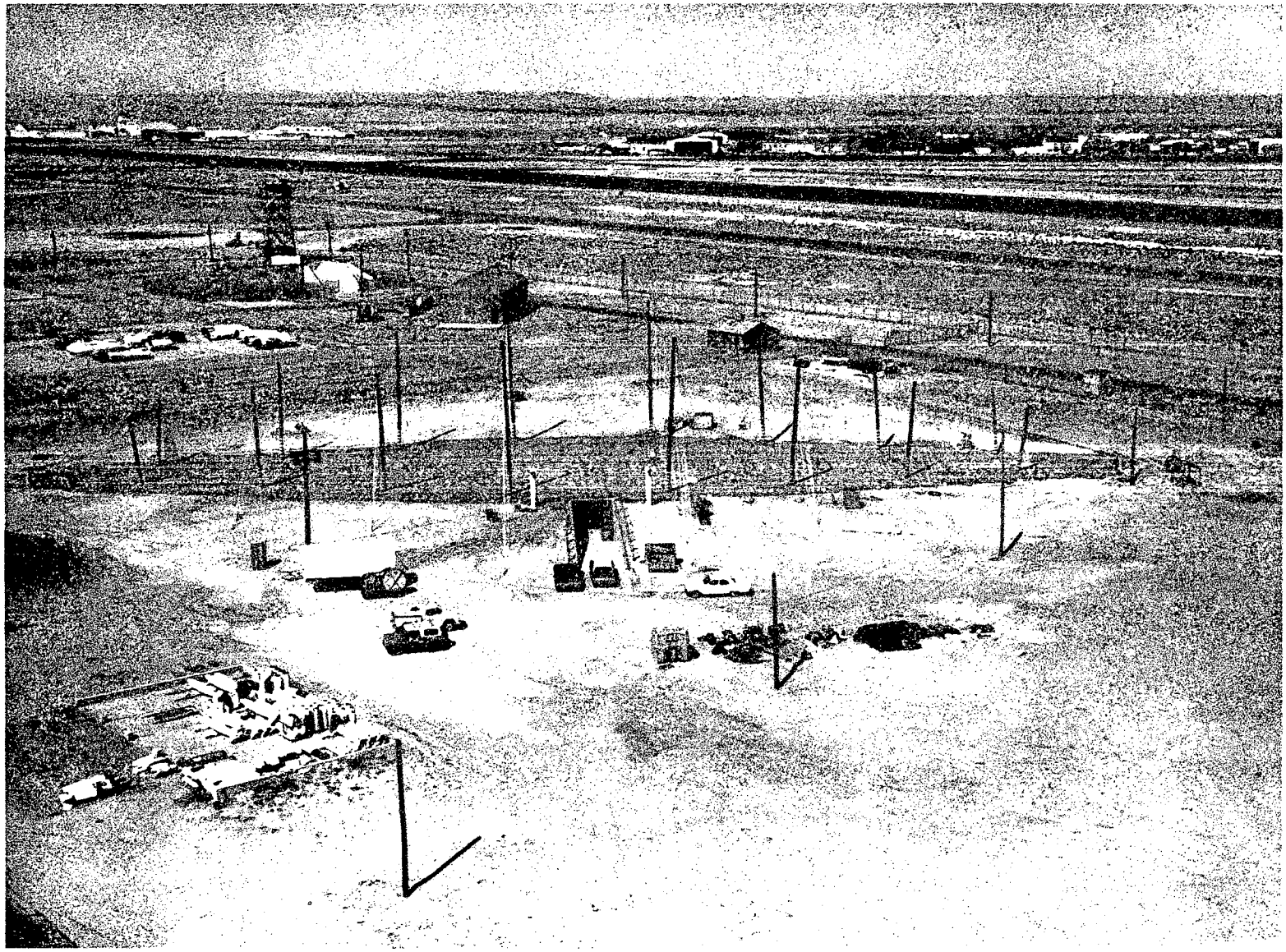

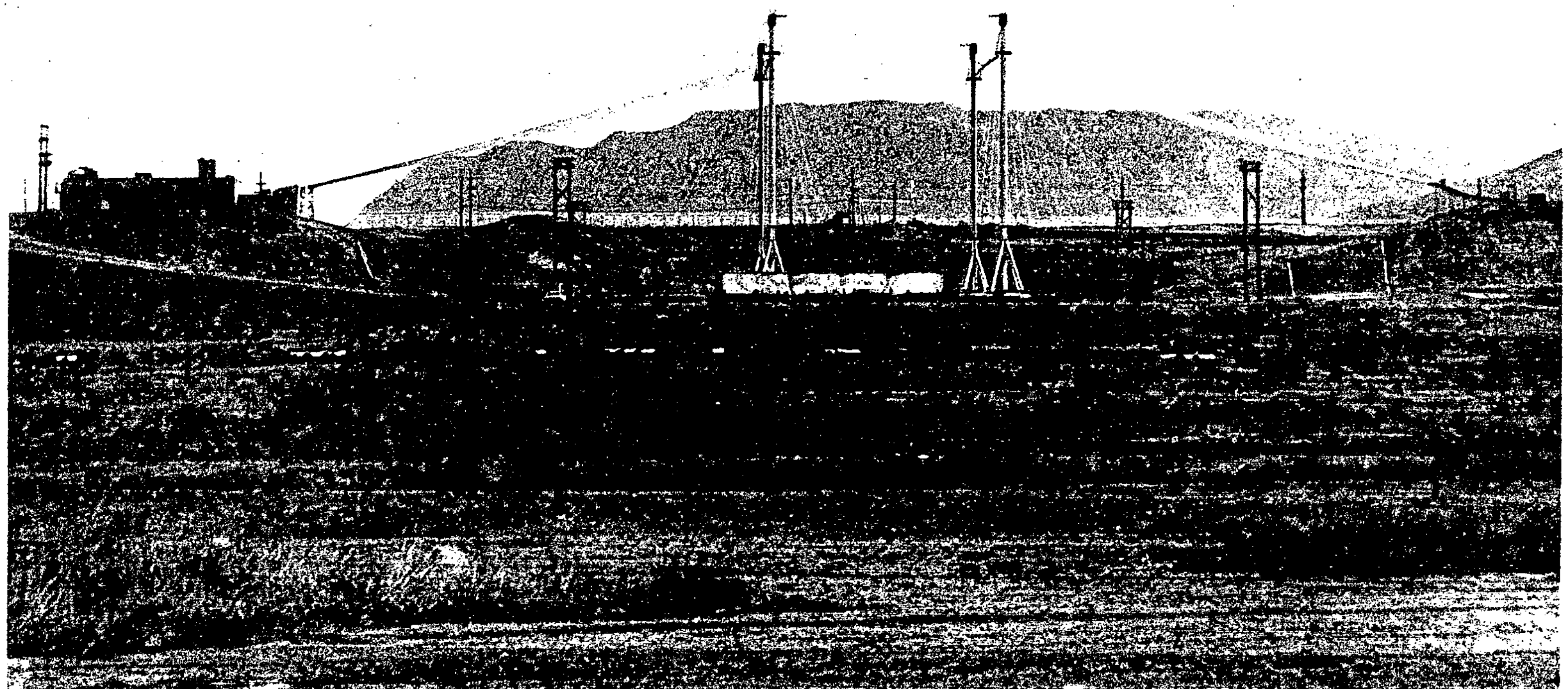

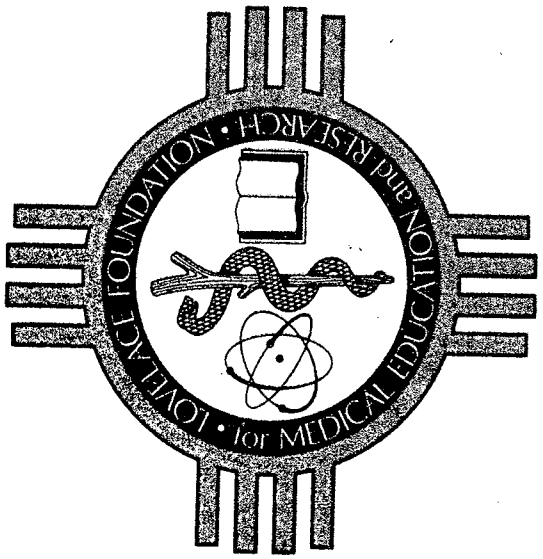
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