UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
HOUSTON LIGHTING & POWER COMPANY	)	Docket No. 50-466
	)	
(Allens Creek Nuclear Generating Station, Unit 1)	)	

NRC STAFF SUPPLEMENTAL TESTIMONY OF GERALD E. GEARS

ON TRANSMISSION LINES/HEALTH EFFECTS

MARRACK 2(b), RENTFRO 2

Q: Will the witness please state his name, place of employment, and duties he performs?

A: My name is Gerald E. Gears and I am employed by the Environmental Engineering Branch, Division of Engineering, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission. I am a Senior Land-Use Analyst. A copy of my professional qualifications is attached to this supplemental testimony.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to respond to the following contention:

Marrack Contention 2(b) and Rentfro Contention 2 allege that the potential health hazards associated with living in proximity to high-voltage transmission lines have not been adequately evaluated.

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Q: Have you participated in the review of the potential environmental impacts associated with the operation of the proposed Allens Creek Nuclear Generating Station (ACNGS) transmission system?

A: Yes.

Q: What has been the nature of your involvement in that review and assessment?

A: My involvement has included the review of the terrestrial ecology and land use sections, including those pertaining to transmission lines, and I helped prepare Sections S.3.4, S.5.1.2 and S.11.2 for the Final Supplement to the Final Environmental Statement (FSFES).

Q: In response to the above-listed contention, what is the general scope of this supplemental testimony?

A: The Staff has considered the effects of electromagnetic field on humans in the Sections S.3.4, S.5.1.2, and 5.11.2 of the FSFES. The purpose of my testimony is to supplement the above document as related to humans, plants, and animals.

Q: What are the potential environmental effects of electromagnetic fields in biological systems?

A: There are two areas of prime concern: induced shock currents and potential biological effects of electromagnetic fields.

Q: Would you explain in greater detail each of these areas?

A: Yes. I will first outline the issue of potential shock hazards associated with operating extra-high voltage (EHV) systems such as the proposed 345,000 volts (345 kV) Allens Creek transmission system.

Q: What causes electrical "shocks" from transmission lines?

A: The proposed 345 kV transmission lines will induce an electric charge and proportional voltage on insulated conducting objects on or near the right-of-way (R/W). Transient currents (or "spark discharges")[1,2] are encountered when an individual comes into contact with a charged object that is at a different electric potential than the individual. If the potential difference between the object and the individual is sufficient, a small arc ("spark") may be established just prior to initial contact. Once contact is established a continuous current flows through the body of a person who may be in contact with the charged object. This current is called a steady state (or "short circuit") current[1,2]. The level of the induced charge will vary with a host of factors, including: voltage (which affects electric field strength), transmission line conductor-to-ground clearance (which is affected by line loading and ambient temperature) (the lower the clearance, the greater the charge), size of the insulated conducting object (the larger the object, the greater the induced charge),

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1 United States Department of Interior. Electric and Biological Effects of Transmission Lines, A Review. Bonneville Power Administration, June 1977.

2 United States Department of Agriculture. Electrostatic and Electromagnetic Effects of Overhead Transmission Lines, Rural Electrification Administration, May 1976.

degree of insulation of the conducting object, and spatial relationship of the insulated conducting object to the transmission line conductors. The levels of steady state or transient currents experienced will also be affected by the degree to which the person touching the insulated object is effectively grounded.[3]

Q: What physical injury results from a shock hazard?

A: For steady state currents, direct physical harm occurs only above the "let-go" level -- where involuntary muscle contraction makes the person unable to release the conducting object. The minimum "let-go" level for men is about 9 milliamperes (mA) and that for women about 6 mA. Adequate data are lacking on the "let-go" threshold for children. This threshold has been estimated to be in the range of 4.5-5.0 mA.[4] The National Electrical Safety Code[5] specifies 5 mA as the maximum allowable short circuit current for the largest vehicle expected beneath a transmission line. At some point above the let-go level, respiratory arrest and consequent suffocation may occur if the current flows through certain parts of the body for a sufficient time. Below the let-go level but above the threshold of perception, steady state current flow may cause anything from mild surprise to a sudden, involuntary "startle" reaction of part or all of the body. While about 1% of children and small adults can perceive steady state currents of about 0.1 mA, the threshold of perception for 50% of the population is

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[3] T. D. Bracken. 1976. Field Measurements and Calculations of Electrostatic Effects of Overhead Transmission Lines, IEEE Trans on Power Apparatus and Systems, Vol. PAS-95(2):494-504.

[4] ITT Research Institute. Evaluation of Health and Environmental Effects of EXTRA HIGH VOLTAGE (EHV) Transmission. Prepared for U.S. Environmental Protection Agency, February 1979.

[5] National Electrical Safety Code. Institute of Electrical and Electronics Engineering, Inc., National Bureau of Standards, ANSI C2. 1977.

about 1.0 mA[6,7]. For transient currents, spark discharges at the maximum levels predicted for the proposed 345 kV transmission line will not cause any direct permanent physical harm.

Q: Can any precautions be taken by the applicant to reduce the potential for physical injury?

A: To protect people not only against direct permanent physical harm but also against possible indirect or secondary injury that might occur from an involuntary reaction to a shock current -- such as from jerking a hand back and catching it in moving machine parts, a program of grounding -- or grounding and bonding of stationary, fixed conducting objects on or near the R/W (like metal buildings, roofs, or fences), without any change in voltage or facility design will be initiated by the applicant (FES Suppl. Sect. S.11.2 and S.A-23) to prevent shock hazards. Vehicles which may use or cross the R/W, however, present a more difficult problem, since they may not be equipped with grounding straps or chains. The National Electrical Safety Code covers this problem in Section 23 - Clearances.

Q: What will be the applicant's proposed minimum clearances and the effects of such clearances?

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6 C. F. Dalziel and W. R. Lee. 1969, Lethal Electric Currents, IEEE Spectrum, February, pp. 44-50.

7 J. C. Keesey and F. S. Letcher. 1970, Human Thresholds of Electric Shock at Power Transmission Frequencies, Arch. Environ. Health, Vol. 21:547-552.

A: Minimal clearances that will meet the 5.0 mA steady state current limit (National Electrical Code Sec. 232, B.1.c) for all vehicles reasonably anticipated to travel on or across any part of the R/W will be provided by the applicant. No currents above that limit would be experienced from touching a school bus, a milk tanker, a bucket truck or a combine operating on the R/W away from roads.

Q: What are your conclusions about potential shock hazards based upon the foregoing analysis?

A: I believe that HL&P's present design clearances that maintain a maximum inducted current of 5.0 mA rms when the largest anticipated truck, vehicle or equipment under the line is short-circuited to ground for the proposed 345 kV line provide adequate protection from induced shock currents.

Since the applicant has committed to design the 345 kV line for a 5.0 mA steady state limit, it is highly improbable that indirect injuries, caused by involuntary reaction to shocks will occur. Therefore, these proposed transmission facilities do not require additional protection features. If additional data from research and other sources determine the necessity of additional protection against indirect injury, operating conditions providing some type of public educational program about these hazards may be warranted.

Q: Are there any other possible harmful effects to humans other than shock hazards, of electromagnetic fields?

A: Yes, electromagnetic fields may result in other potential biological effects of humans.

Q: What are the sources of those potential biological effects?

A: There are two other potential sources of biological effects: corona discharge resulting in the generation of ozone; and electric field effects other than shock hazards.

Q: How do transmission lines generate ozone?

A: Corona is a phenomenon that occurs in the immediate vicinity of the transmission line conductors due to the strong electric fields that exist at the conductor surface. Corona discharge frequently results in the product' n of ozone.

Q: How much ozone is generated by extra high voltage (EHV) transmission lines such as the ACNGS 345 kV lines?

A: Results of six extensive field tests concerning the measurement of ozone from EHV lines indicate that ozone concentrations due to transmission lines were barely distinguishable from the ambient background ozone concentrations.[8,9] All reported field measurements resulted in no more than 1 ppb ozone under fair weather conditions. During foul weather,

[8] G. F. Schiefelbein. Alternative Electric Transmission Systems and Their Environmental Impact. NUREG-0316. Battelle Pacific Northwest Laboratories, August 1977.

[9] IIT Research Institute. Evaluation of Health and Environmental Effects of Extra High Voltage (EHV) Transmission. Final Report Prepared for the Environmental Protection Agency. February 1979.

small amounts of ozone (20 ppb) were measured at the approximate height of a transmission line but no ozone was detected at ground level. Thus, if ozone is produced, it should not result in any significant or detectable health effect.

Q: What other electric field effects may result in potential biological effects to humans?

A: The passage of an electric current through any unshielded conductor produces both electric and magnetic fields in the surrounding medium. The effect of electric fields on humans has been and presently still is being studied extensively throughout the world. As transmission designs result in larger and larger voltages, more intense fields that cover wider areas may result. For an overhead AC transmission line, the three separate phases create an interference pattern so that the strongest field exists in the area below the outer phases, approximately 20 to 60 feet from the centerline. The field drops off moderately as one moves closer to the centerline, and falls off rapidly as one moves further away from the facility. A 345 kV facility may produce a peak electric field of 5 to 6 kilovolts per meter (kV/m) at ground level, dependent upon conductor configurations, and the field drops off to about 1.6 kV/m at the edge of right-of-way. The magnetic field produced by a high voltage transmission line has similar characteristics. The maximum calculated magnetic profile at 1.5 m above the ground is about .6 G (gauss).

Q: Are any harmful biological effects expected from magnetic fields under transmission lines?

A: No. Magnetic field levels at which biological effects occur are generally much higher than levels under power lines. Safety standards for whole body exposure to magnetic fields for long periods have been recommended at 200 to 300 G[10] (gauss) as opposed to the 0.6 G produced by high voltage transmission lines.

Q: Are there any current guidelines established for exposure to electric fields?

A: Precautionary electric field guidelines have been established by the Russians for substation and transmission line workers[11]. More recently the Russians established general exposure guidelines for the local population and agricultural workers[12]. Using the Russian general population guidelines, HL&P's 345 kV lines would be permitted*.

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[10] U.S. Department of Interior (Bonneville Power Authority), pp. 17-19.

[11] "Rules and Regulations on Labor Protection at 400, 500, and 750 kV AC Substation and Overhead Lines of Industrial Frequency (in USSR)". 1972. Translated by G. G. Knickerbocker in Special Publication No. 10, Power Engineering Society (IEEE), 1975.

[12] Y. I. Lyskov, Y. S. Emma, and M. D. Stolyarov. 1975. Electric 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. Trans. by G. G. Knickerbocker in Special Publication No. 10, Power Engineering Society (IEEE), 1975.

* These guidelines established higher acceptable gradient standards of transmission lines in accordance with these direct quotations (from Lyskov, et al. 1975):

(continuation of footnote from page 9):

"In designing the O. H. 750-1150 kV line, considering that cumulative effect of the field due to an infrequent and non-systematic 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."

However, a Russian paper by U. D. Dumanskiy, et al. entitled "Hygienic Evaluation of Electromagnetic Field Generated by High-Voltage Power Lines" (in Gigiyena I Sanitariya-No. 8:19-23, 1976), obtained by the Staff, states that laboratory test animals (albino rats) undergo changes in behavioral reactions when subjected to fields in the range of only 1 to 5 kV/meter. These field gradient levels are considerably below the general population standards quoted above.

Current research is being funded and guided by the Federal Interagency Advisory Committee on Electric Field Effects on which NRC Staff actively serves to determine if more definite guidelines are necessary.

Q: What are the biological effects to humans as a result of exposure to electric fields?

A: Current research has produced statistically significant effects in the areas of neonatal development, endrocrinology, hematology, neurophysiology, neurochemistry, urine volume and chemistry, sympathetic nervous system, and behavior in tests on mice and rats.[13] These effects were found at field strengths scaled to man of about 4-20 kV/m[14,15]. A 4-20 kV/m field strength is typical for the maximum values measured near the ground under 345-745 kV transmission lines near the center of the R/W. Maximum field strengths at the edge of the R/W, as stated earlier, fall off rapidly and would be about 1.6 kV/m at the edge of the R/W or less for a 345 kV line and, therefore, biological effects to humans would not be expected.

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[13] Biological Effects of Electric Fields on Small Laboratory Animals. R. D. Philips; Battelle Memorial Institute-PNL; Richland, Washington. U.S. Department of Energy; Office of Electric Energy Systems - 1980 Contractors Review Meeting; November 18-19, 1980.

[14] S. V. Kolesnikov and B. A. Chukhlovin. 1978. To the Interaction Phenomena Between Industrial Frequency AC (50-Hz) Field and the Organism of a Human and an Animal. Translated from "Letters to Journal of Technical Physics" (USSR). Volume 4, Issue 15, August 12, 1978, pages 935-939.

[15] W. T. Kaune and R. D. Phillips. 1980. Comparison of the Coupling of Grounded Humans, Swine, Rats to Vertical, 60-Hz Electric Fields. Bioelectromagnetics 1:117-129.

Q: Are you familiar with any public hearings dealing with the health and safety of transmission lines?

A: Yes, I have followed the extensive New York State Public Service Commission (NYPSC) hearings on the health and safety of 765 kV overhead transmission systems. Upon completion of these hearings, the NYPSC commissioners concluded that "risks, if any, of long-term exposure to 765 kV transmission in the areas traversed by PASNY's line and any future 765 kV lines will be no greater than those, now widely accepted, of long-term exposure to the 345 kV lines operating throughout the State." (State of New York Public Service Commission. Opinion No. 78-13. Cases 26529 and 26559. June 19, 1978, p. 41.)

Q: What are your conclusions and recommendations concerning the health and safety of HL&P's 345 kV lines?

A: Based on the foregoing facts, it is my opinion that there is no evidence at this time that the operation of 345 kV power lines will have a significant effect on the health of humans. If ongoing research were to conclude that protective measures were warranted, a variety of actions could be considered including, but not limited to: increasing the width of right-of-way to limit the field strengths to which the public would be exposed at the edge of the right-of-way; potential rights-of-way users be given specific warnings of possible risks; use of shield wires or other types of retrofitting techniques which could reduce field gradients to a prescribed level.

Although the staff does not believe that additional protective measures are warranted at this time, we are keeping abreast of these studies and will take any new information into consideration during our review of transmission line operation at the operating stage.

Q: Were the effects of electromagnetic fields on plants and animals addressed in the FES or FSFES?

A: The Staff did not address the question of field gradient effects on plant or animal life along the transmission line in the FES or the FSFES for two distinct reasons:

(1) It is our position that any effects attributed to the electric field on humans would generally include large animals, since most of these animals have a territorial range extending beyond the right-of-way and therefore would not be exposed for long periods to field gradients. Smaller animals which exhibit a more limited range would most likely be shielded extensively from electric field gradients at ground level by surrounding shrubs, grasses, etc., and therefore would not receive a high cumulative exposure dose.

(2) Field tests and studies of biological ill effects of field gradients conducted on plants and animals have generally indicated that no significant effects are attributable to electric fields predicted to occur from the operation of 345 kV systems.

Q: What does the latest data pertaining to electric field effects on agriculturally related plant life indicate?

A: Results of ongoing research[16] on electric field effects on growth and development of plants and animals indicate that neither gross injuries nor gross abnormalities were apparent from a 50 kV/m field.

Some minor physical damage, barely perceivable along corn, bluegrass, and alfalfa leaf tips was indicated in fields from voltage gradients of 25 kV/m and above. The same series of studies investigating electric field effects on small animals indicate that no major abnormalities in behavior, activity, or outward appearance have been demonstrated from high fields of 50 kV/m. The preliminary results further substantiate published data which to date have not indicated any hazardous effects to laboratory and agricultural animals from fields generated from existing transmission systems[17].

Q: What are your conclusions about potential effects of electromagnetic fields on plantsand animals?

A: Based on the above findings, which indicate no substantial damage to plants or animals, I do not believe that changes in the applicant's proposed

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16 The Effects of High Voltage Electric Lines on the Growth and Development of Plants and Animals. J. W. Bankoski, H. B. Graves, and G. W. McKee. Proceedings of the First National Symposium on Environmental Concerns In Right-Of-Way Management. Mississippi State University. 1976.

17 Biological Effects of High Voltage Electric Fields: State-of-the-Art Review and Program Plan. IIT Research Institute, Chicago, Illinois. November 1975.

transmission line design are warranted. As in the case of human ill effects, additional extensive studies are currently being conducted. The Staff is keeping abreast of these studies and of any guidelines resulting from them, and will reconsider the impacts of the transmission line operation prior to or at the time of the operating stage review, taking into consideration any new information. At that time, mitigating measures, if warranted, can be considered and implemented.

PROFESSIONAL QUALIFICATIONS
GERALD E. GEARS
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C.

I am currently employed as a Senior Land-Use Analyst in the Office of Nuclear Reactor Regulation, Division of Site Safety and Environmental Analysis, in the Environmental Specialists Branch, USNRC. As a member of the Terrestrial Resources Section of this branch since 1974, I have responsibility for the review of applicants' Environmental Reports at both Construction Permit and Operating License Stage for completeness and environmental acceptability of proposed projects as they may affect natural ecological resources, agricultural resources, land use pattern and other impacts on the terrestrial environment. It is also my responsibility to provide written evaluation of terrestrial resources for inclusion in both FES-CP and FES-OL Stages. I also act as a consultant to other NRC branches and provide analyses of terrestrial problems through technical assistance requests from other groups. Review and modifications of applicants' environmental technical specifications at the operating license stage is another of my responsibilities. My work also involves the preparation of environmental standard review plans, regulatory guides and staff position papers dealing with terrestrial resources. As a Terrestrial Ecologist I have among other tasks in recent months prepared analyses on alternate site selection and alternative transmission corridors for the Palo Verde Nuclear Generating Station Units 1, 2, and 3, written the terrestrial resource-related sections for the Palisades Nuclear Generating Station and Arkansas One, Unit 2, Environmental Impact Statements (EIS), and the Indian Point, Unit 2, and Indian Point, Unit 3, EISs pertaining to closed-cycle cooling alternatives, and the Watts Bar-OL EIS. I have prepared and presented testimony as the staff's expert witness in the contested North Anna Nuclear Power Station, Marble Hill and Seabrook environmental hearings. I am a member of the Interagency Advisory Committee on Electric Field Effects from High Voltage Lines which is charged with the task of funding research to develop safety guidelines for transmission lines. I am also the NRC representative on a Fish and Wildlife Service Review Committee charged with the development of a manual for improving transmission system rights-of-way construction and operation practices.

I have a Bachelor of Science in Agronomy from Oregon State University (1972), a Bachelor of Arts and Science in German and Russian from Villanova University (1966), and a Master of Science in Agronomy from the University of Florida (1974). While at the University of Florida (1972-1974), I undertook research in the areas of Resource Management and Ecosystem Modeling. My formal education program has encompassed and emphasized studies in agriculture, economics, botany, soil fertility, including tropical and arid soils, plant physiology, crop production, range resources, aquatic plant ecology, computer modeling and resource assessment techniques. Using analog and digital computer hardware combined with an energy based resource analysis language, I developed and expanded various ecosystem models for the study of alternative uses of native vegetation and urban wastes in cooperation with members of the Department of

Agronomy, the Department of Forestry (Resource Management Section) and the Department of Environmental Engineering of the University of Florida.

From 1969 to 1970, I was employed as a teacher at Aquinas Institute, a secondary school in Rochester, New York.

From 1966 to 1969, I was employed as an agricultural extension agent by the Indian Government in cooperation with the Peace Corps in the State of Maharashtra. I organized and conducted demonstration projects in this capacity in order to investigate the feasibility of employing alternative methods of crop production in village level situations. This assignment provided experiences in the utilization and evaluation of alternative agricultural resource management methods in a unique cultural setting.