THE CONNECTICUT SITING COUNCIL
DOCKET NO. 272

Application of Northeast Utilities Service Company
for a Certificate of Environmental Compatibility
and Public Need for a new 345-kV Electric Transmission Line Facility
between Scovill Rock Switching Station in Middletown
and Norwalk Substation in Norwalk

Supplemental Testimony Concerning Laboratory Studies of Effects of EMF

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Q. What is the purpose of this testimony?

A. The purpose of this testimony is to provide the Siting Council with updated information regarding the current status of laboratory studies concerning the potential adverse effects of EMF.

Q. In addition to epidemiologic studies regarding effects of EMF on humans, have there also been laboratory studies examining the effects of EMF on cells and animals?

A. Yes.

Q. Has there been an authoritative independent review of laboratory studies regarding the potential adverse effects of EMF?

A. Yes. The most recent independent panel that reviewed the detailed laboratory studies was the National Institute of Environmental Health Sciences (NIEHS) Working Group which reviewed the interaction of extremely low frequency EMF with biological systems in Durham, NC in March 1997. A second and final meeting was held in Brooklyn Park, Minnesota in June 1998. The results of these meetings are published as *Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields Working Group Report: Chapter 4.7 In vitro and mechanistic studies* [1].

Q. Did the NIEHS Working Group conclude that laboratory studies in cells and animals provided evidence that higher levels of EMF cause mechanistically plausible toxic effects?

A. Yes. The NIEHS Working Group stated that, based upon animal and cell laboratory studies available in 1998, there was plausible evidence that higher levels of EMF mediate toxic effects.

The Working Group stated, "*In-vitro* experiments permit the testing of potentially toxic exposure under controlled conditions, typically at doses well above those encountered in the environment. Studies of the genotoxic effect of such exposure and effects on cell proliferation, alteration of signal transduction pathways, and modification of differentiation processes can serve to identify agents with potential carcinogenic effects or effects on other health end-points…"

The Working Group summarized its conclusions with regard to higher levels of EMF, "A limited number of well-performed studies provide moderate evidence for mechanistically plausible effects of EMF greater than 0.1mT *in vitro* at end-points generally regarded as reflecting the action of toxic agents.

[This conclusion was supported by 27 Working Group members; there were 2 abstentions.]"

Q. Did the NIEHS Working Group conclude that, based upon laboratory studies in cells and animals available in 1998, a toxic effect of lower levels of EMF was an open question?

A. Yes. The NIEHS Working Group stated that, based upon animal and cell laboratory studies available at the time, there was weak evidence of the toxic effects of lower levels of EMF. The report of the Working Group indicates that the toxic effect of lower levels of EMF, with regard to laboratory studies, was an open question in 1998, as demonstrated by their recommendation that additional laboratory studies with lower levels of EMF should be conducted.

The Working Group summarized its conclusions regarding lower levels of EMF, "There is weak evidence for an effect of fields lower than approximately 0.1mT."

In conclusion, the Working Group recommended, "The potential role of magneto-chemical processes in the coupling of ELF fields to biological systems suggests that extension of both theoretical and experimental studies of intensity regimes below 0.1 mT should be conducted."

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies examining whether EMF less than approximately 0.1mT is associated with adverse effects?

A. Yes. There have been a substantial number of studies examining the effects of EMF levels both greater than 0.1mT and field levels less than or equal to approximately 0.1mT. While a few of these studies have not shown significant effects, a substantial number of these published studies have demonstrated mechanistically plausible significant effects of EMF less than approximately 0.1mT at end-points generally regarded as reflecting the action of toxic agents.

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies, and also studies with exposure to actual overhead power lines, examining whether EMF less than approximately 0.1mT is associated with increased DNA damage?

A. Yes. There have been studies examining the effect of EMF levels both greater than 0.1mT and field levels less than or equal to approximately 0.1mT on DNA damage. DNA damage can either directly cause mutations or impede the normal repair process. DNA damage is a plausible cellular mechanism for causing cancer. Focusing exclusively on the NIEHS threshold of less than or equal to 0.1mT, Ivancsits et al.[2] demonstrated that 5 minutes on/10 minutes off 50 Hz fields for as little as one hour and with a field strength as low as 0.035mT induced dose-dependent and time-dependent DNA single-strand and double-strand breaks in

cultured human fibroblast cells. Svedenstal et al. [3] demonstrated that, in whole animal studies in which mice were exposed to 50 Hz EMF directly from a 220 kV overhead transmission line with 0.006-0.008mT EMF levels for 32 days, DNA damage was observed in brain cells as compared to sham-exposed animals (mice housed outside but away from the power line). Moreover, Svedenstal [3] demonstrated that exposure to high voltage transmission lines also caused a significant reduction in circulating lymphocytes, a significant reduction in spleen organ weight, and a significant increase in immature red blood cells. Each of these abnormal findings is consistent with disturbed function of the blood production system. Additionally, Lai and Singh [4] demonstrated that in whole animal studies, in which rats were exposed to 0.01mT for 24 hours, low intensity ELF EMF caused significant increases in single and double strand DNA breaks in brain cells. These investigators further demonstrated that the DNA damage appeared to be induced by EMF-mediated production of free radicals, a common and plausible mechanism for DNA damage.

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies examining whether EMF less than approximately 0.1mT is associated with changes in the stress response?

A. Yes. There have been studies examining the effect of EMF levels both greater than 0.1mT and field levels less than or equal to approximately 0.1mT on the stress response. Changes in gene transcription with particular attention to growth-control genes have been implicated as a plausible cellular mechanism resulting in cancer. Lin et al. [5] demonstrated that 0.008mT EMF caused increased transcription of Heat Shock Protein 70 (HSP70) DNA resulting in increased HSP70 message. Lin et al. [6] in additional studies further showed that 0.008mT EMF caused induction of a promoter for the c-myc proto-oncogene, a finding associated with transformation of cells into uncontrollable cell growth. Tokalov et al. [7] demonstrated that an EMF dose as low as 0.010mT resulted in significant induction of heat shock protein genes in leukemia cells in culture. Di Carlo et al. [8] demonstrated that exposure of chick embryos to 0.004mT or more of EMF for only 30 minutes was associated with significant protection from stress. Subsequently, Di Carlo et al. [9] demonstrated that longer term EMF exposure at 0.008mT for four days caused a subsequent significant decrease in survival of chick embryos and a reduced protection from stress. Separately, Rajendra et al. [10] showed that several neurotransmitters, including norepinephrine, tyrosine, and glutamine were significantly changed by continuous exposure of chick embryos to EMF levels of 0.005 – 0.1mT for up to 15 days.

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies examining whether EMF less than approximately 0.1mT is associated with changes in electron transport and generation of oxygen free radicals?

A. Yes. There have been studies examining the effect of EMF levels both greater than 0.1mT and field levels less than or equal to approximately 0.1mT on electron transfer. Electron transfer reactions have been implicated between base pairs in

double stranded DNA [11]. Additionally, changes in various reactions, including energy transport reactions, affect cell growth. Perhaps most importantly, some electron transport reactions can result in formation of oxygen free radicals which mediate oxidative damage to DNA and proteins within cells. Blank and Soo [12, 13] demonstrated that a 0.028mT field accelerated the rate of electron transfer in a simple model reaction called the Belousov-Zhabotinski reaction, and in common cellular reactions including energy transport with the sodium hydrogen ATPase reaction and the cytochrome oxidase reaction. As demonstrated by Rosenspire et al. [14], very low frequency alternating fields cause significant increases in the amplitude of the natural cellular oscillatory pattern of the sodium hydrogen ATPase reactions in white blood cells. Rosenspire et al. [14] further demonstrated that the AC electric field-induced increase in sodium hydrogen ATPase reactions generated oxygen free radicals and subsequent DNA damage in white blood cells. Lai and Singh [4] confirmed oxygen free radical generation and subsequent DNA damage in whole animal studies with ELF EMF exposure of 0.01mT for 24 hours.

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies examining whether EMF less than approximately 0.1mT is associated with changes in signal transduction?

A. Yes. There have been studies examining the effect of EMF levels both greater than 0.1mT and field levels less than or equal to approximately 0.1mT on signal transduction. Signal transduction including calcium fluxes is associated with the mechanism of action of many prototypical cancer-causing compounds. McCreary [15] showed in cell cultured lymphocytes that the stage in the cell cycle and the nature of the T cell receptor were important contributors to a significant effect of 0.1mT EMF on calcium flux. Koch et al. [16] demonstrated in isolated membrane vesicles that extremely low frequency EMF between 7-72 Hz and amplitudes of 0.013 – 0.114mT, with a static DC background, altered calcium flux. Nie and Henderson [17] show that the growth-promoting enzyme MAP kinase is significantly activated with 0.1mT ELF EMF in human leukemia and breast cancer cells, and in rat fibroblasts. Lindstrom et al. [18] observed that 0.1mT EMF for only 5 minutes resulted in phosphorylation of the T cell receptor complex, an important step in signal transduction in lymphocytes.

Q. Since the 1998 NIEHS Working Group report, have there been laboratory studies that provide evidence that EMF less than approximately 0.1mT causes mechanistically plausible toxic effects which may cause cancer?

A. Yes. Since the NIEHS Working Group called in 1998 for laboratory examination of whether EMF less than approximately 0.1mT is associated with significant biologic changes, a substantial number of such studies have been published in the scientific literature. Most of these published studies have demonstrated that EMF less than or equal to approximately 0.1mT is associated with significantly increased DNA damage, changes in stress response, acceleration of electron transport chemical reactions, generation of oxygen free radicals, and alterations in signal transduction.

Hence, since the 1998 NIEHS Working Group review, the plausible mechanisms for EMF causing cancer in laboratory studies have been extended to below the 0.1mT threshold. A broad spectrum of laboratory evidence supporting multiple potential mechanisms for lower intensities of ELF EMF to cause cancer in humans has been provided in the scientific literature.

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