

# **Electromagnetic Fields from High Voltage Transmission Lines**

**A report to Mr. Michael Smith, T.D., Minister for Energy**

**T. McMANUS, PhD  
Chief Technical Advisor**

**Department of Energy  
25th November, 1988**

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1. The first part of the document is a list of the names of the members of the committee who have been appointed to the various sub-committees.

## SUMMARY

The potential adverse health effects of the electromagnetic fields produced by high voltage electricity transmission lines have been investigated in the light of representations made to the Minister for Energy in connection with the 220 kV Carrickmines to Arklow power line.

The investigation comprised a detailed review of relevant scientific literature, discussions with leading researchers in a number of national laboratories, a meeting with the World Health Organisation, and visits to four North American power utilities who have undertaken major studies on the subject.

The main findings of this investigation are:

- 1) There is no widespread agreement among research workers that electromagnetic fields from power lines present a potential hazard to the health of people or animals.
- 2) What evidence there is of adverse health effects comes from a small number of epidemiological studies where an association has been observed between cancer in children and the proximity of their homes to concentrations of overhead electricity cables. Many other epidemiological studies have observed no such association.

3) The position of governments, as evidenced in official statements or in published reports from Departments of Health, and of the World Health Organisation at this time is

- that all have taken the possibility of a health effect seriously,
- that none consider the risk to be so great as to require a prohibition on the construction of new power lines or any reduction in the voltage of existing ones,
- that while some consider there is no risk, others consider that any effect, if established, will prove to be very small
- that all support further research.

4) Much additional research is now being undertaken which will avoid the deficiencies of most of the studies

~~undertaken up to now.~~ In consequence, this additional research is very expensive and will take several years to complete.

5) Meanwhile some advisory bodies have recommended that limits to public exposure to electromagnetic fields be applied as an interim measure.

- 6) In the State of Florida an interim standard limiting public exposure to electromagnetic fields has been proposed for new power line construction that is more stringent by far than that considered appropriate by any other jurisdiction or advisory group.

In Ireland electric power consumption, power line voltages, and concentrations of power lines are all well below the levels that are typical of Western Europe, North America and most industrialised countries. The strengths of both electric and magnetic field in the vicinity of the Carrickmines-Arklow power line, when the line is switched-in, will be well within those limits even being proposed for Florida. Field strengths will certainly not exceed any of the Florida standards at either St. Catherine's or Kilmacanogue schools.

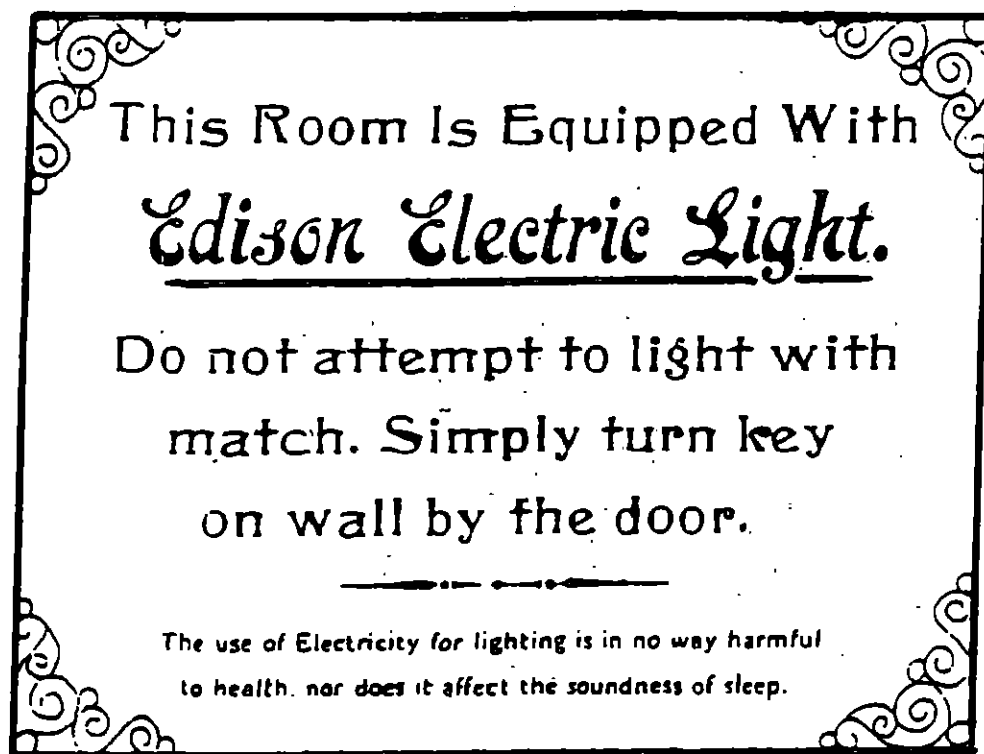
There is no scientific basis at this time to justify a further delay to the energising of the Carrickmines-Arklow 220kV transmission line.

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*Issued during the introduction of electricity supply to New York in 1882.*

Fig. 1.

## **1 Findings and Recommendations**

### **a) Background to Investigation**

The Electricity Supply Board (ESB) has recently completed the construction of a 220kV transmission line from Carrickmines in Co. Dublin to Arklow in Co. Wicklow. Concern has been expressed by local residents in regard to the possible health effects arising from the electromagnetic fields that will be produced by this line when it is in operation. Following representations made to the Minister for Energy, the Minister decided that the switching-in of the transmission line should be delayed while he made a further assessment of the situation. As part of this assessment the Minister directed the Chief Technical Advisor in the Department of Energy to prepare a report. His report was to review relevant scientific literature dealing with the possible health effects of electromagnetic fields; determine the positions being taken by regulatory authorities, international advisory bodies, and leading national laboratories on the subject; and assess the relevance of this to Ireland, in particular to the Carrickmines - Arklow transmission line. This document is that report.

### **b) Initial Observations**

One of the first discoveries made by the author when reviewing the vast literature on the possible health effects of electromagnetic fields was that he is not the first to do this, nor even the fifty first. It turns out to be a well trodden path. National, state, and provincial governments; international agencies; national research laboratories;

Individual researchers, electric power utilities, and objectors to electric power utilities, all regularly commission and undertake literature reviews of the subject. With a wide selection of scientific and sometimes not so scientific research findings to choose from, reflecting all shades of opinion, it is not difficult to produce a collection of statements and findings that can be advanced to support any pre-determined position the reviewer wishes to take. This has been particularly true of a number of television and newspaper reports which have contributed in no small measure to the present level of public concern - a concern which is worldwide and not confined to Ireland or indeed to Co. Wicklow. Electric utilities do not escape criticism. They have also been accused in the past of collating favourable anthologies of quotations to reassure, or as their opponents would say, mislead the public.

**c) Electric and Magnetic Fields**

The strength of an electric field is related to the voltage in the circuit, while the magnetic field strength is related to the current flowing in the wire. The two fields, when considered together are usually referred to as the electromagnetic field. Where high voltages and high currents occur together, such as in high voltage electric power transmission lines, strong electromagnetic fields are produced.

**d) Epidemiological Studies**

The main evidence to implicate electromagnetic fields in adverse health effects is to be found in epidemiological studies. Epidemiology is the statistical analysis of the incidence of specific human diseases and their relationship to the activities and environmental exposures of specific categories of the population at large.

The epidemiological evidence of adverse health effects arising from exposure to electromagnetic fields is less than overwhelming. Of some 25 studies relating the incidence of cancer to occupational exposure 13 indicated a positive association and 12 no association with adverse health effects. Of 15 studies relating the incidence of cancer to residential exposure almost two thirds failed to find an association. Among 10 other studies which searched for health effects other than cancer 5 indicated some adverse effect while 5 did not.

All published epidemiological studies up to now have suffered from one major deficiency - no reliable measures of actual exposures to electromagnetic fields were made. In nearly all cases the extent of field exposure was determined by a surrogate measure such as 'job title' in the case of occupational studies and the number of overhead electric cables in the case of residential studies. In some cases the surrogate measures were augmented by spot measurements of magnetic field strength. However there have been occasions when the spot measurements so taken served to confound the

observed association instead of reinforcing it. The most notable case of this happening was in the Savitz study of childhood cancer in Denver (Savitz, 1987b).

Savitz found an association between the incidence of childhood cancer and magnetic fields in Denver which, in the words of the study's sponsors, "with the assumption of a causal effect ..... would mean that 10-15% of all childhood cancer cases are attributable to magnetic fields".

In this quotation, taken from the Final Report of the Panel of Scientific Advisors to the New York State Power Lines Project (Ahlbom et al, 1987), the concentration of overhead wiring is used as a surrogate for magnetic field exposure. However when Savitz correlated cancer incidence against his spot measurements of magnetic field strength he found that cancer incidence decreased as field strength got stronger. This latter point was rarely mentioned in the flood of articles, interviews, and documentaries that followed publication of the New York report in July 1987. Even less attention was paid to the 15 other research projects sponsored by New York State as part of the Power Lines Project.

#### **e) Reaction to Savitz' Epidemiological Study**

A report that magnetic fields from power lines may be responsible for up to 15% of all childhood cancer could not be ignored and the response of regulatory authorities and health advisory bodies since has been threefold:

1. Committees of scientists were assembled to look at Savitz' data and at all other relevant epidemiological and biological studies reported in recent years.
2. Major epidemiological studies were initiated which involve examining much larger populations than Denver and included, for the first time, measurements of actual magnetic field exposures of subjects over sample periods.
3. Further biological research was planned (i) to determine whether electromagnetic fields could induce cancer or other health effects in laboratory animals or changes in human cells and (ii) to elucidate the mechanisms causing any observed effects.

**f) Biological Studies**

Biological studies involving the exposure of animals or cells to electromagnetic fields suffer a difficulty not encountered in other biological studies where the effect of a chemical, for example, is being investigated. In the case of the chemical its concentration can be increased until an effect is observed, and in this way its toxicity related to other chemicals.

However, if the strength of the electromagnetic field is increased to too high a level, currents can be induced that can heat the subject and give it electric shocks. The results of many early biological studies are now widely discounted because it would now appear, in the light of experience, that the effects being attributed to electromagnetic fields were actually produced by associated electric shocks or overheating

not relevant to the transmission line situation. In order to avoid such effects the 14 biological projects sponsored by the New York State Power Lines Project limited exposures to about ten times the levels of those one might find in the vicinity of a 765 kV transmission line. The results of these studies are discussed in Section 3.4.4. Suffice to say, at this juncture, no significant biological effects were observed.

Many influential scientists would still contend that the only biological effects produced by electromagnetic fields are those due to temperature rise from induction heating. Others dispute this, and one scientist in particular, Dr. W. Ross Adey, whom more than one North American power utility has described as a "respected opponent" is particularly scathing of this view (U.S. Congress, 1987). However other researchers are now disputing Adey's key hypothesis - that electromagnetic fields upset the communications function of the cell membrane and ultimately produce changes that promote cancer (ADEY, 1987), and one group of workers (Albert et al, 1987) reported recently that they had failed to replicate Adey's findings.

#### **g) Official Statements of Opinion**

In recent years many official and quasi-official bodies, have produced 'statements' and 'opinions' on the subject of electromagnetic fields and their potential for affecting health. The main conclusions to be drawn from the positions adopted by the many countries, states, and organisations quoted in the extracts set out in Section 4 are essentially these:

- . All take the possibility of a health effect seriously.
- . None consider the threat of a possible health effect to be so great as to suggest we should do anything at this time to stop the construction of new power lines or reduce the voltage of existing ones.
- . Some consider electromagnetic fields pose no threat.
- . Others consider that if an effect is proven it is likely to be a very small one.
- . All would endorse further research efforts.

#### **h) Future Epidemiological Studies**

It is appropriate at this time to say a word or two about 'further research efforts'. It is more than likely that if an adverse effect is finally proven it will be done through epidemiological research. Now childhood cancer is still fortunately a rare disease. In order to establish a causal relationship between magnetic fields and cancer it will be necessary to monitor a very large number of cases over many years to obtain statistically significant results. Such studies will require typically a population of around 10-20 million people (e.g. Southern California, Canada, Upper New York State).

This new kind of study, embracing large populations, wide geographical areas, and the need to provide equipment to monitor the magnetic field exposures of all cases and controls can generally only be done with government support. It involves huge expenses and needs a high degree of co-ordination and co-operation among all concerned. However, it should provide some definitive answers. In 1992, by which



time many of the major studies from the United States, Canada and Sweden will have reported, we should have a much better indication of the magnitude of the risk, if any, to the public and to electricity industry workers posed by electromagnetic fields.

1) What is being done meanwhile?

This question has been addressed by a number of regulatory authorities and by national and international advisory groups. The answer has generally taken the form of proposed interim standards or threshold exposure limits to electromagnetic fields. These limits represent the maximum field strengths to which the public or workers might be exposed without risk to health. Unfortunately there is a wide divergence of view as to what constitutes an acceptable threshold. In the case of exposure of the public to magnetic fields the following proposals have been made or are under active consideration.

~~-----~~ maximum continuous exposure levels: ~~-----~~

International Radiation Protection Association:	50 microtesla
U.K. National Radiological Protection Board:	174 microtesla
State of Florida:	5 microtesla

- maximum occasional exposure for a few hours per day:

International Radiation Protection Association:	500 microtesla
U.K. National Radiological Protection Board:	760 microtesla
State of Florida:	10 microtesla

In the case of public exposure to electric fields there is closer agreement among the recommendations:

- maximum continuous exposure levels:

International Radiation Protection Association: 5000 volts/metre

U.K. National Radiological Protection Board: 2600 volts/metre

State of Florida: 1500 volts/metre

- maximum occasional exposure for a few hours per day:

International Radiation Protection Association: 10,000 volts/metre

U.K. National Radiological Protection Board: 12,000 volts/metre

State of Florida: 8000 volts/metre

It should be noted that the U.K. NRPB will be shortly revising its recommendations concerning exposure of the public to 50Hz electromagnetic fields (NRPB, 1988c). These new less stringent recommendations are outlined in section 4.2.7. and are based on the exposure levels below which there is no danger of electric shock or burn from induced electric currents in the body or from contact with large ungrounded objects in the fields.

The Florida electric and magnetic field limits are as yet unapproved limits to be applicable only for new power line construction. They are by far the most stringent proposals under consideration by any jurisdiction.

#### j) The Irish Scene

The incidence of childhood leukaemia in Ireland is similar to the incidence among white children in Europe and North America. The incidence is very evenly spread across the country and shows very

few areas where, statistically speaking, the incidence is either above or below that expected. In contrast, while the amount of electricity generated in Ireland has increased nearly five fold since 1962, our per capita use of electrical power is well below the European average and is only just over half that of France and Germany. When concentration of power generation is considered (power generated per square km) as a surrogate for concentrations of transmission lines, Ireland has one of the lowest concentrations in Europe - only about one tenth that of West Germany or Belgium.

The purpose of the foregoing information is to indicate that should power lines indeed be implicated in adverse health effects, these health effects should be more pronounced in some of our European neighbours.

**k) The Carrickmines-Arklow 220kV Transmission Line**

Coming finally to the issue of the Carrickmines-Arklow power line. The main problem being raised is that of the proximity of the line to two schools, Kilmacanogue and St. Catherine's.

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The 220kV line was built over the same route as an existing 110kV line. The schools were already there. The key question is: "Does this power line present a danger to the health of the children in the schools or in the playgrounds".

An analysis of the situation leads to the conclusion that there is no health risk on the basis of present knowledge. In arriving at this conclusion the following approach was adopted:

- . Of all the jurisdictions that have considered all of the available evidence for and against the hypothesis that electromagnetic fields from power lines present a hazard to health, Florida has arrived at a proposed standard more stringent than any other extant.
- . The Florida magnetic field standard is some ten times more stringent than even that now under active consideration by the International Radiation Protection Association (IRPA)
- . The electric and magnetic fields strengths at the schools and in the playgrounds were calculated for both the Kilmacanogue and St. Catherine's schools. Under worst case conditions - applying conditions which would generate the strongest magnetic fields - the calculated field strengths were found to be well within the proposed Florida standards.

There is therefore no basis for judging the transmission line to be a health hazard or to delay switching-in the line.

## 2. Acknowledgements

The writer is deeply indebted to a large number of individuals and organisations who provided assistance to this investigation. Without exception all concerned gave freely of their time, their experience and their opinions. It is also thanks to this assistance that the writer was able to assemble a collection of many of the latest and in some cases, as yet unpublished, reports on electromagnetic fields. These proved invaluable.

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### 3. Electromagnetic Fields and Health Effects

#### 3.1 Background to Public Concern

Public concern about possible hidden dangers from electricity and radio is not a new phenomenon. When Edison first introduced electric lighting to the citizens of New York in 1882, besides warning his customers not to use matches to activate the light bulb, he also felt obliged to reassure users that:

"The use of Electricity for lighting is in no way harmful to health, nor does it affect the soundness of sleep".

(Fig 1).

In the 1920's when the BBC began radio broadcasting, the Emperor of Japan sent a sternly worded note of protest to King George V, requesting that England "desist from sending radio waves over Japan for they will surely affect the Japanese people" (BBC, 1974). By the mid 1930's the succession of droughts that affected the south central United States and helped create the Dust Bowl ~~and the associated human misery immortalized by John Steinbeck,~~ was widely blamed at the time on the burgeoning number of radio stations inflicting their output on the skies so driving the clouds away (Russell, 1988). This summer another drought has afflicted the American mid-west but this time the cause is being attributed to the 'greenhouse effect', the consequence it is claimed of filling the air with too much carbon dioxide.

Carbon dioxide, radio waves, and electricity are everywhere. There are no events, be they good or bad, fortunate or unfortunate, that do not take place in their presence. It is not

surprising then that electromagnetic fields, which are ubiquitous and little understood, should be especially suspect when a problem has difficulty finding a cause.

In the 1960's and 1970's the main concerns involving power lines and electromagnetic fields were over their aesthetic impact, their interference with radio and television reception, over problems with noise and problems from induced currents. While no one was able to do much about the visibility of transmission pylons, the increasing transmission voltages being employed by the utilities minimised their number. The effects of power transmission on radio and television reception were initially aggravated by the higher voltages employed but were eventually greatly reduced by improved design and operation, as was the noise problem.

Induced currents however are a different matter. These currents are produced whenever a conductor, that is anything that conducts electricity such as a large tractor or a small human, is placed in the electromagnetic field that surrounds high voltage AC transmission lines. There is no easy way to prevent currents being induced, and they can be vividly demonstrated by holding a fluorescent tube under a high voltage powerline and watching it glow. This effect is also employed from time to time to generate alarm in the unwary by the unscrupulous. The response of power companies to the problem of induced currents has been aimed mainly at educating and informing the public and offering specific advice on control measures to those whose livelihoods involve utilising land under or near power line rights-of-way. So, for example, Ontario Hydro set up a high voltage power line demonstration

centre near Toronto which became virtually a tourist attraction. Other utilities duplicated the fluorescent tube trick in the vicinity of motor car ignition coils and CB radio antennae.

Essentially, the approach of the utilities was to help the public better understand electricity, high voltages, and electromagnetic fields in order to reduce irrational fears. There the whole problem of electromagnetic fields might have remained as far as the general public were concerned, until 1976 when the staff of the United States Embassy in Moscow discovered that they had been unknowingly subject to microwave radiation for over 20 years.

From 1953 to 1976 staff employed by the U.S. Embassy in Moscow had been subject to a low level microwave radiation of strengths up to 0.15 watts per sq. m. (equivalent to 7.5 volts per metre) emanating from outside the embassy. The U.S. authorities were concerned at the possible health implications of this exposure and commissioned a study (Lilienfeld et al, 1978) which compared the health, mortality, and cause of death of 4827 embassy employees and dependents with that of 7561 employees and dependents who had worked in other U.S. embassies in Europe. This exhaustive survey was unable to establish any difference in the two groups that could be attributed to microwave exposure. However the public concern generated by this episode remained high and interest in the subject of electromagnetic radiation became much more widespread among the scientific community.

Prior to 1976 there had been no significant co-ordinated research effort on the possible adverse health effects of electromagnetic fields. Although some work had been carried out in Russia in the

1960's (Asanova and Rakov, 1966; Sazonova, 1967), the results of this research went largely unnoticed until published in English (Knickerbocker, 1975).

The first widely available report of adverse biological effects was a paper to CIGRE\* in Paris (Korobkova et al 1972) where it was reported that Soviet switch-yard workers exposed to electric fields of up to 26kV/m suffered headaches, fatigue, and reduced sexual potency. Although efforts by other researchers later failed to find such symptoms among workers employed in similar occupations in a number of European and North American utilities, the Russian findings were widely reported at the time.

One of the consequences of the Russian report was the ammunition it provided to objectors at the public hearings held in New York in 1973 in connection with two power line projects. One project was a request by the Power Authority of the State of New York for authorisation to build a 765kV line from Utica, N.Y. to Quebec to facilitate importation of power from Hydro-Quebec. The second project was for a similar 765kV line from Rochester, N.Y. to Oswego, N.Y. required by the Rochester Gas and Electric Corporation and the Niagara Mohawk Power Corporation. It was these public hearings in 1973 that led directly, if slowly, to the now famous New York State Power Lines Project the findings of which were published in July 1987. This report has become the touchstone for most current judgements on the subject of electromagnetic fields health effects. The New York State Power Lines Project is discussed in Section 3.4.4.

\* CIGRE: The standing International Conference on Large High Voltage Electric Systems.

Back in 1976, while the New York State Public Service Commission was still engaged in hearings on the potential health and environmental effects of the two 765kV transmission line projects and with the Moscow embassy scandal making headlines, one of the first laboratory reports of adverse biological effects was published (Marino et al, 1976). This was a study of the effects of electric fields on rodent mortality and growth. At fields of 15kV/m increased mortality, retarded growth, and changes in blood chemistry were observed. However, as the researchers admitted, the electric shocks the rodents picked up from metal eating and drinking troughs as a results of induced currents might have been responsible for some of the effects. Nevertheless the findings were widely reported - electromagnetic fields were now newsworthy.

In 1977 hostility to a power line project grew into organised opposition and outright violence. Some sixteen towers were overturned during the construction of a 440 mile  $\pm$  400kV DC line from North Dakota to St. Paul-Minneapolis. Some \$4.8 million in additional security costs were incurred. Cost over-runs and claimed health effects were later investigated by the U.S. Comptroller General. The opposition was confined to Minnesota and was centred on a belief that the line wasn't needed, the right-of-way had been improperly obtained, and that health would be endangered. Studies initially by the Minnesota Environmental Quality Board in 1977 and then by the Comptroller General of the United States in 1979 found no evidence to indicate a threat to human health. However soon after the line was energised some people, again in Minnesota, reported adverse effects on their families and animals. Further assessments by a specially convened

Science Advisory Committee for the State of Minnesota again concluded there was no risk, although in a minority report one member (Bramble, 1982) concluded "that it is more likely than not that the ..... HV DC transmission line represents a potentially significant hazard to human health and welfare" and added that "air ions produced by this line are the most probably agent of this hazard". Follow up studies on dairy farms close to and far away from the line found no differences in milk production, calving intervals, and rate of culling for reproductive problems. During all of this time very little controversy developed in North Dakota where two thirds of the line was located.

The next major milestone, some would say 'bombshell', in the developing electromagnetic fields - health controversy was the epidemiological study of the incidence of childhood cancer in Denver (Wertheimer and Leeper, 1979). This was the first suggestion that exposure to electromagnetic fields could be associated with death. It was this report that stimulated most of the public concern and media coverage, and much of the epidemiological and biological research in the years that followed.

Purely by chance observation Dr. Nancy Wertheimer, a researcher engaged by a group of Denver parents whose children had cancer, noticed a high concentration of overhead power distribution cables near many of the homes. She undertook an epidemiological study which indicated that cancer risk appeared to be 2 to 3 times greater in homes near concentrations of overhead wires. In the

study it was also suggested that the return earth or neutral currents along household plumbing could be contributing to the problem via the magnetic fields such currents generated.

In the 1980's the number of epidemiological studies multiplied as efforts were made to see if Wertheimer and Leeper's findings could be duplicated elsewhere. The adverse biological effects reported by Marino, Becker and some others stimulated regulatory authorities, national laboratories, and the electrical utilities to fund a vast amount of laboratory research work which had the general aim of trying to see whether electromagnetic fields could induce or promote cancer in animals or adversely affect the normal functioning of living cells. The main result of all this effort, besides confusion engendered by conflicting findings, was the shift in emphasis from electric fields to magnetic fields. If one thing had become clear it was that the problems of determining the effects of electromagnetic fields on human health were not going to be easily resolved. But it did appear that if health was at risk it was from the magnetic component, not the electric component, of the electromagnetic field.

The increasing volume of research on the subject over recent years has been accompanied by an increasing number of reviews of this research. Many of these reviews were commissioned by governments, regulatory authorities and various international organisations to assist them in decisions concerning new power lines, in preparing standards for environmental exposure, or in meeting obligations to provide objective advice to protect the health of workers and the general public. Of twenty-one reviews published in Europe and North America between 1981 and 1985, while a number referred to

"considerable uncertainty" about the nature, magnitude, and indeed the existence of a health risk from exposure to low frequency electric and magnetic fields, only two came down on the side of positive health effects. In a book entitled "Electromagnetism and Life" (Becker and Marino, 1982) the authors concluded:

"It is therefore clear from the laboratory studies, that because non-thermal electromagnetic fields are capable of altering physiological functions, chronic exposure to them in the environment can result in some risk to health".

In a later book (Becker and Selden, 1985) the authors stated their findings even more forcibly:

"..... electromagnetic fields vibrating at about 30 to 100Hz, even if they are weaker than the earth's field, interfere with the cues that keep our biological cycles properly tuned; chronic stress and impaired disease resistance result. Second, the available evidence strongly suggests that regulation of cellular growth processes is impaired by electro-pollution, increasing cancer rates and producing serious reproductive problems".

Despite the weight of scientific opinion at that time being of the view "if there is a problem it's a very small one, so let's do more research", the widespread publicity given by the press and television to the views of Dr. R. O. Becker and Dr. A. Marino ensured, in North America at least, that any application by a power company to obtain authorisation to build a high voltage power line would be strongly contested by local residents.



In 1987 two major reports were published which reflected the change in emphasis from the electric field component of electromagnetic radiation to the magnetic field component.

The first report was that by the World Health Organisation (WHO, 1987) in their Environmental Health Criteria Series. This report was in essence a comprehensive review of the literature on the health effects of magnetic fields undertaken by a group of the leading and most eminent researchers from across the globe.

The second major report of 1987 was the "Final Report on the Biological Effects of Power Line Fields" produced by the Scientific Advisory Panel to the New York Power Lines Project (Ahlbom et al, 1987). This report assessed the results of a five-year, \$5 million study to determine whether there are health hazards associated with electric and magnetic fields produced by 60Hz power transmission lines, especially 765kV lines.

Both the WHO and New York reports are discussed in more detail later. However, let it be said at once that there was nothing in the WHO report nor in the results of fifteen of the sixteen research projects funded by the New York Power Lines Project to generate more than a prudent if mild concern among legislators. This concern would be to ensure a minimum of further research was carried out to establish the level of risk, if any, presented by power line magnetic fields and the need, if any, to place further constraints on power line construction. There was certainly no justification for becoming alarmed about the possible adverse health effects of electricity transmission lines on the basis of the findings of the WHO and fifteen out of the sixteen New York

projects. But the sixteenth put the cat among the pigeons, or as the dictionary would say, 'it introduced a violently disturbing new element'. The sixteenth project was the Savitz study.

Since the Wertheimer and Leeper report of the incidence of childhood cancer in Denver, debate had raged among epidemiologists on the validity of the 1979 study findings. Many criticisms were made of the methodology used which it was said did not take sufficient account of procedures to avoid statistical bias. Some workers suggested that the magnetic fields produced by household appliances would have far exceeded those contributed by outside distribution lines (Miller, 1980). However when the Electric Power Research Institute commissioned an independent re-assessment of the Wertheimer and Leeper report (Roth, 1985), this confirmed many of its findings, including a significant association between wiring configuration (the concentration of outside power lines) and cancer. Yet studies similar to the one in Denver carried out in Rhode Island (Fulton et al 1980) failed to show a connection.

The New York Power Lines Project commissioned Professor D.A. Savitz to repeat the Denver investigation of Wertheimer and Leeper, but with the benefit of all the criticisms of the earlier study to improve the methodology and a new cohort of childhood cancer cases. Where Wertheimer and Leeper had investigated a sample of 344 cases between 1950 and 1973, Savitz studied all 356 cases between 1976 and 1983. There was therefore no overlap of data. The Savitz study was included in the final report of the New York Power Lines Project, and was published as a scientific paper more recently (Savitz et al, 1988).

Savitz reported not only a correlation between measured magnetic fields and wiring configuration, he also found that the relative risk of childhood cancer in areas where magnetic fields were strongest, as implied by wiring configurations, was twice what one would normally expect. In other words where normally one can expect one case of childhood cancer in 10,000 children each year, in Denver this incidence is doubled to 2 per 10,000 in the vicinity of power line concentrations. If the relationship between magnetic fields and cancer were causal and if the Denver findings were applicable to the whole United States, then it could be hypothesised that 10-15% of all childhood cancer is attributable to magnetic fields.

In the months following the publication of his findings Savitz became the best known epidemiologist in North America. Public concern over electromagnetic fields reached new heights. In November 1987 the United States Congress held special hearings on the subject of the health effects of power transmission lines. In January 1988 the United States Dept. of Energy revised its guidelines for environmental impact statements on power line projects to include assessments of public and occupational health risks arising from exposure to electromagnetic fields. Major epidemiological studies were initiated or planned in California, New York State, Canada, and England. An international study involving Ontario, Quebec, and France was also begun.

Committees of experts assembled to plan laboratory research programmes aimed at a definitive determination of the role of magnetic fields in mutagenesis, teratogenesis, and cancer induction, promotion and growth. Yet more reviews of the rapidly

increasing body of literature on the subject were undertaken and commissioned. Power utilities, government health departments, national research laboratories, and Dr. Savitz were all obliged to publish statements of their position on the magnetic field question. This was necessary in order to counteract some of the more extreme interpretations being placed on Savitz' work by the popular press and 'investigative' television programmes, and to offer some reassurance to the general public.

In his letter (Savitz, 1987a) addressed to "Persons concerned about reports of electromagnetic fields and childhood cancer" Savitz made the following points:

- . "It should be kept in mind that we have not proven that magnetic fields cause cancer. Subsequent research will indicate whether we are on the right track or whether our results are in error".
- . ".....our study is not sufficiently convincing to warrant drastic action by homeowners"
- . "The question of what distance from what types of power lines is "safe" is not really answerable: We don't yet know with certainty that any distance is unsafe".

When in August 1988 the writer (T.McM) met the Secretary to the World Health Organisation Task Group which had prepared the WHO Environmental Health Criteria Report No. 69 on Magnetic Fields and asked him about whether he would modify any of WHO's conclusions

in the light of the further publications in this area over the previous 12 months, Dr. Waight stated emphatically that he would change nothing. In fact he saw no need to revise Report No. 69 before 1992-1993 when it would come round for revision under the normal course of events.

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### 3.2 The Research

There is a vast literature on electromagnetic fields (EMFs). Keeping up with it is a full time job. Several organisations maintain databases. Ontario Hydro employ two staff full time preparing abstracts and maintaining their BEEF (Biological Effects of Electromagnetic Fields) Database to which outside organisations can subscribe.

The literature can be conveniently grouped into four broad categories.

- . Epidemiological Studies
- . Biological Studies involving Animals
- . Biological Studies involving Cells
- . Literature Reviews of the above

### 3.3 Epidemiological Studies

#### 3.3.1 Published Studies

Epidemiological studies fall into two broad groups:

- . studies involving residential exposure
- . studies involving occupational exposure

Some 49 epidemiological studies were identified as having been completed between 1979 and 1988.

These are summarised in three tables covering

- . cancer incidence and occupational exposure (Table 3.1)
- . cancer incidence and residential exposure (Table 3.2)
- . epidemiological studies of other health effects (Table 3.3)

In these tables the comment in the column headed 'Risk' is taken from the researchers own conclusions or from an assessment of the study undertaken by an appropriate expert or group. The latter are identified where appropriate. For some of these studies an expert opinion on the quality of the epidemiology was also obtained. This information is not included in the tables, but does influence the comments which follow.

**Table 3.1      Epidemiological Studies of Cancer Incidence and Occupational Exposure**

Reference	Subject	Risk/Comment
Wiklund et al (1981)	Swedish telecommunications workers vs Swedish population as a whole	No increased cancer risk (WHO, 1987)
Milham (1982)	10 electrical occupations in Washington State vs. non electrical occupations	Excess deaths due to leukaemia (BPA,1986)
Wright et al (1982)	11 electrical occupations in Los Angeles	Trend for increased leukaemia (BPA,1986)
McDowall (1983)	The occupations of all men dying from leukaemia in England & Wales (1970-72)	Higher incidence of leukaemia in electrical trades (Theriault, 1984)
Coleman et al (1983)	10 electrical occupations in S.E. England	Higher incidence of leukaemia, particularly among telegraph/ radio operators (Theriault, 1984)
Vagero & Olin (1983)	Swedish electrical trade workers	No excess of leukaemias, but a significant increase in throat cancer (WHO,1987)



**Table 3.1**

Reference	Subject	Risk/Comment
Swerdlow (1983)	Electrical and electronics workers in England and Wales	Increase in eye melanoma (WHO,1987)
WHO (1984)	Review of epidemiological studies prior to 1984	The studies have serious deficiencies in epidemiological design (authors)
Milham (1985a)	An update of Milham's 1982 study with 3 more years of data	8 out of 9 electrical occupations showing increased leukaemia (BPA,1986)
Pearce et al (1985)	New Zealand electronic equipment assemblers, TV repairmen, linesmen, power stations operators	Study indicates leukaemia risks more associated with exposure to metal fumes and chemicals rather than EMF (author)
Lin et al (1985)	Electrical occupations in Maryland	Increased brain tumours (WHO,1987)

**Table 3.1**

Reference	Subject	Risk/Comment
Milham (1985b)	Radio hams in Washington and California	Increased incidence of certain leukaemias (BPA,1986)
Gilman et al (1985)	U.S. white male coal miners	higher incidence of acute myelogenous leukaemia may be due to benzene, and of chronic lymphocytic leukaemia to EMF (authors)
Vagero et al (1985)	Swedish electrical trade workers	No excess of leukaemia. An excess of malignant melanoma was associated with soldering (WHO,1987)
Calle & Savitz (1985)	10 electrical occupations in Wisconsin	No significant excess in leukaemia mortality (BPA,1986)

**Table 3.1**

Reference	Subject	Risk/Comment
Olin et al (1985)	Cancer mortality among Swedish electrical engineers vs architects	Cancer incidence among engineers half that expected, but there was an increase in skin cancer (BPA,1986)
Gallagher et al (1985)	Electrical workers in Western Canada	No increase in eye cancer(BPA,1986)
Savitz (1985)	Review of literature prior to 1985 - human cancer risk and emfs	The literature does not support the presence of a causal association (author)
Tornqvist et al (1986)	Swedish linesmen and power workers vs. other blue collar workers	No excess of leukaemia or brain tumours. Some excess of urinary organ cancer (WHO,1987)
Flodin et al (1986)	Electrical workers, case control study	Increased leukaemia among electrical workers (Repacholi, 1988)

**Table 3.1**

Reference	Subject	Risk/Comment
Stern et al (1986)	Electricians and welders in a US Navy dockyard	The absence of increased risk for all leukaemia or for acute leukaemia among emf-exposed welders does not support the hypothesis that the observed excess risk for leukaemia among the electrical trades is due to EMF exposure (authors)
Thomas et al (1987)	Electrical workers, case control study.	Increased brain tumours among exposed workers (Repacholi, 1988)
McLaughlin et al (1987)	Swedish electrical workers, a proportional incidence study	No increase in brain tumours observed (Repacholi, 1988)
Lin (1987)	Power company employees in Taiwan, a case control study.	Increased cancer risk (Repacholi, 1988)
Milham (1988)	Follow up to 1985 study of radio hams.	Mortality due to acute myeloid leukaemia was significantly elevated (author).

From the 25 references given in Table 3.1 it can be seen that 13 indicate a positive association between cancer and occupational exposure to emf while 12 fail to find an association. None of the studies adequately measured the electromagnetic fields to which workers were exposed. In most cases this exposure was inferred by the occupation job title or by the proximity of electrical equipment in the workplace. Job titles are rarely consistent with type of work even among companies working in the same industry. Workers may only be close to certain equipment when it is shut down and undergoing repair. Confounders such as exposure to metal fumes and solvents, particularly in the electronics industry, were sometimes mentioned but rarely measured or quantified. In many cases the studies fail to meet acceptable epidemiological standards.

Critical reviews of some of the more widely publicised studies were undertaken by the School of Occupational Health at McGill University (Theriault, 1984) and more recently by an IERE\* Working Group under Dr. Leonard Sagan as convenor (IERE, 1988). As the comments made by these reviewers also cover several of the epidemiological studies listed in Tables 3.2 and 3.3., which now follow, these will be discussed later.

\* International Electric Research Exchange, an organisation of research organisations funded by electric utilities.

**Table 3.2**      **Epidemiological Studies of Cancer Incidence and Residential Exposure**

Reference	Subject	Risk/Comment
Wertheimer & Leeper (1979)	Childhood cancer in Denver over a 24 year period (1950 - 1973)	Cancer risk 2 to 3 times higher for residences near to sources of high current (BPA, 1986)
Fulton et al (1980)	Childhood cancer in Rhode Island	No relationship between leukaemia and electric power line configurations (BPA, 1986)
Wertheimer & Leeper (1982)	Adult cancer in Colorado	Excess cancers of the CNS, uterus, breast, and lymphomas near high current wiring (WHO, 1987)
Aldrich et al (1984)	Cluster of 5 sinus tumours in Florida	Proximity of a 69KV powerline cited as possible factor. Homes were also close to a lead smelter (BPA, 1986)

**Table 3.2**

Reference	Subject	Risk/Comment
Coleman et al (1985)	A case control study of leukaemia in the UK and proximity to power lines	No increased risk of leukaemia (WHO,1987)
Myers et al (1985)	A further case control study of childhood cancer in the UK and proximity to powerlines	No association found (WHO, 1987)
Rodvall et al (1985)	Incidence of cancer in Alfta, Sweden, and proximity to HV lines	No increased cancer (WHO, 1987)
Roth (1985)	A re-analysis of the studies by Wertheimer & Leeper (1979) and Fulton (1980)	Confirmed results of both earlier studies (BPA, 1986)
Spitz & Johnson (1985)	Occupations of fathers whose children had died of CNS tumours over a 14 year period in Texas, a case-control study.	Electrical occupation doubled the risk. For electronics workers risk was increased to nearly 12 times. (BPA,1986) Possible confounder is exposure to chemicals (authors)

**Table 3.2**

Reference	Subject	Risk/Comment
Tomenius (1986)	Childhood cancer in Stockholm over a 16 year period	No increased leukaemia but greater numbers of CNS cancers near powerlines (WHO,1987)
McDowell (1986)	Mortality among 7631 people living near powerlines in UK.	No association between magnetic fields and leukaemia and most other cancers (BPA, 1986)
Coleman & Bell (1987)	A case control study of leukaemia and electrical transmission equipment in the UK.	No leukaemia risk observed (Repacholi, 1988)
Savitz et al (1988)	Childhood cancer in Denver (1976-1983), a case control study.	A twofold increase in the incidence of cancer among children living close to high current wiring configurations (adapted from author's abstract)



**Table 3.2**

Reference	Subject	Risk/Comment
Stevens et al (1988)	Adult leukaemia in western Washington State (1981-1984) a case control study	Neither the directly, measured magnetic fields nor the surrogate values based on wiring configurations were associated with acute non-lymphocytic leukaemia (author)
Kraft (1988)	A study of the relationship of a leukaemia cluster in Gateshead, England, to high voltage power lines and equipment	No evidence that proximity to power lines or substations was implicated in the cluster (author).

**Table 3.3      Epidemiological Studies for Effects other than Cancer**

Reference	Subject	Risk/Comment
Strumza (1970)	Influence on health of nearby HV lines	Those living within 25m of powerlines did not purchase more medicines nor consult their doctors more frequently than others (BPA, 1986)
Reichmanis, Marino et al (1979)	Suicide and electromagnetic field strength in UK West Midlands	A correlation between suicide and emf was reported (BPA, 1986)
Perry, Marino et al (1981)	Suicide and front door magnetic fields in UK West Midlands	Mean magnetic fields were slightly higher (87nT*) at suicide residences than 71nT for the controls (BPA, 1986)

[\*nT = nanotesla]

**Table 3.3**

Reference	Subject	Risk/Comment
Smith (1982)	Comment on the Perry, Marino et al (1981) study	The lack of a clearcut dependence of the suicide incidence on the magnetic field intensity suggests that the apparent correlation may be purely fortuitous (WHO, 1987)
Nordstrom et al (1983)	Pregnancy outcome among wives of Swedish power plants workers	A statistically significant reduction in "normal" pregnancy outcome where father worked in high voltage switchyard (author)
Haupt and Nolfi (1984)	A community health survey among 438 people living near to an HVDC line	No significant or consistent relationships between exposure and perceived health problems (author)

**Table 3.3**

Reference	Subject	Risk/Comment
Grandofolo et al (1986)	Health of railway workers at 258 interconnection and conversion substations (220kV)	No differences have been found between the exposed and the control groups. Typical exposures were 5kV/m and 15 microtesla.(authors)
McDowell (1986)	Mortality of 8000 living near UK electrical transmission facilities in 1971, followed over a 12 year period to 1983.	The study did not support previously reported associations of exposure to EMFS with suicide (authors)
Wertheimer & Leeper (1986)	Pregnancy outcome and use of electric blankets and heated waterbeds.	Seasonal patterns in fetal growth and abortion rate could be due to excessive heat or to EMF exposure (author)
Nordenson et al (1988)	Chromosomal aberrations in Swedish 400KV substation workers	Compared to control group the exposed men displayed a statistically significant increase in chromosomal aberrations in cells with micronuclei (author)

Of the 15 studies involving an assessment of the effect of residential exposure to EMF on the incidence of cancer, about twice as many report no association as those that do. However it is the positive studies that have captured attention.

Among the 10 studies which have searched for health effects, other than cancer, which may be attributable to electromagnetic fields 5 indicated some adverse effects while 5 did not.

In an examination (Theriault, 1984) of 10 key studies published between 1979 and 1983 Theriault concluded that Wertheimer's first study (Wertheimer and Leeper 1979) was "good enough to be taken as valid" and that the observed line between childhood cancer and electrical wiring configuration "presents a hypothesis that has yet to be confirmed or disproved". He dismissed however the studies of pregnancy vs occupational exposure and suicide vs residential exposure on the basis that their epidemiological weaknesses precluded acceptance of their findings. Theriault did "definitely not" consider that the studies established a causal link between exposure and leukaemia. He considered that in the case of occupational exposures, the occupations undoubtedly shared other exposures such as metal fumes, solvents, pcbs, and epoxy resins.

The IERE Working Group (IERE, 1988) reviewed 17 major epidemiological studies published between 1979 and July 1986. They did not have the studies of Savitz (Savitz et al, 1988) or Stevens (Stevens et al, 1988) available in final published form, but did state in a footnote that these studies did not materially

affect their findings or recommendations. The Working Group developed criteria with which to judge the value of individual epidemiological studies and then applied these criteria to the 17 studies mentioned.

Their conclusions were:

- . "In general, the 17 studies have weaknesses in that
  - they lack adequate exposure measurements
  - the possible influences of confounding factors are not carefully excluded,
  - there are some inconsistencies in the strength of association (the latter is related to magnitude of risk, size of sample, and statistical confidence intervals)."
- . "It remains impossible to confirm the association of EMF with cancer."
- . "There is therefore strong reason to support further studies which are rigorously designed and executed, and which follow the criteria (set out in the IERE report)."

There is widespread agreement (Repacholi, 1988) that the best of all the studies conducted so far is that of Savitz which indicated an association between wiring codes in Denver, Colorado, and the incidence of childhood cancer. Wiring codes are a measure of the number and characteristics of outside electrical distribution lines providing households with an electrical supply. Savitz classified the outside electrical wiring associated with each home according to one of five categories: buried wire code, very low wire code, low wire code, high wire code, or very high wire code, in ascending order of presumed magnetic field level. The codes correlate approximately with background magnetic field strengths in the home. These background magnetic fields are of the order

of 0.25 microtesla. The fields produced by some domestic appliances can be one hundred times greater. Savitz' study indicated that cancer incidence among children whose homes were adjacent to very high wire codes was 2.3 times more prevalent than that among children whose homes were supplied by buried cables. However Savitz found no evidence of a dose-response gradient by duration of occupancy (i.e. the longer a child spent in an exposed home did not increase the chance of cancer). Savitz also made spot measurements of electromagnetic field strengths in homes occupied by cases and controls under low power conditions (appliances off) and high power conditions (appliances on). There was a very weak association of cancer incidence with increasing field strength under low power conditions and no correlation whatsoever with increasing field strength under high power conditions. Savitz was well aware of the limitations of his study, the main recommendation of which was further examination of the carcinogenic potential of fields produced by power lines and the use of electricity.

The Savitz study was a key 'exhibit' at the U.S. Congressional Hearing into the biological effects of high voltage power lines, held in October 1987 (U.S. Congress, 1987). At this hearing Professor Cole, an eminent American epidemiologist made the following points concerning the Savitz study:

It is a well done study. However while it is widely perceived to be strongly positive it in fact, at best, can only be interpreted as weakly positive.

- . The first reason for this is that the full report produced several hundred estimates of risk which are nearly evenly divided between those which do and those which do not show increase (in cancer).
- . The second reason is that it has been suggested that if EMFs increase the risk of cancer they do this by promoting or increasing the growth rate of cancer. EMFs are not proposed as a complete carcinogen. If EMFs were a promoter or a tumour growth enhancer then children with leukaemia who are exposed to electromagnetic fields should be younger than children with leukaemia who have not been so exposed. Other things being equal a promoting agent will cause a disease to become manifest and be diagnosed earlier. In fact the Savitz study shows that EMF exposed children with leukaemia are older at diagnosis than are non exposed children with leukaemia.
- . The Savitz study represents a fine effort but it must be viewed as only suggestive.

The Savitz study was one of a number of projects undertaken as part of the New York State Power Lines Project. Two of the 16 contracts were for epidemiological studies. Besides the Savitz study was the one undertaken of adult leukaemia in Washington State (Stevens, 1987). The Stevens study was no less rigorous than Savitz'. Wiring configurations were determined and direct measurement of magnetic field strengths were made at each subject's residence. Neither the directly measured magnetic fields nor the surrogate values based on the wiring configurations were associated with acute non-lymphocytic leukaemia.



### 3.3.2 Future Epidemiological Studies

It has become clear that epidemiology is crucial to the understanding of the causes of diseases among human beings and that it is probably through epidemiology that the role of electromagnetic fields in the incidence of cancer will be proved or disproved. Recent evaluations of relevant epidemiological studies by IERE (IERE, 1988) and WHO (WHO, 1988) have led to a broad agreement on the fundamental requirements for future epidemiological studies and have provided guidelines for these studies.

In order to meet these requirements future studies will be need to be large. Only by dealing with a very large population can a relatively rare disease like childhood leukaemia, for example, be related to the many factors that may affects its onset and development. Further it is essential that measurements be made of the actual electromagnetic fields to which both cases and controls are exposed. This second requirement has a number of implications. ~~Firstly-reliable-portable-monitors-must-be~~ available. Secondly there must be funds available to purchase or manufacture a large number of these units. Thirdly the cases must be approached while the cancer is in remission, a requirement which demands a degree of co-ordination and co-operation among researchers and the general medical profession that is unlikely to be achieved without the involvement of government agencies.

These requirements preclude all but the very largest of organisations from undertaking the kind of definitive epidemiological study needed to resolve some of the key EMF issues. Some of the various "mega-studies" that are being considered or have recently got underway are set out in Table 3.4

**Table 3.4      Major Epidemiological Studies Underway or Planned**

Sponsor	Research Centre	Subject	Status
EPRI	John Hopkins University	Leukaemia incidence among telephone co. employees	Underway
EPRI	University of North Carolina	Leukaemia and brain cancer incidence among power workers in 5 U.S. utilities	Commenced 1988 Target Completion 1990-91
EPRI	University of Southern California	Measuring EMF exposures experienced by different electrical occupations and relating these to earlier epidemiological studies.	Underway
EPRI	University of Southern California	EMF exposures experienced by 250 Los Angeles children whose leukaemia is in remission	In mid-course Target Completion 1990

**Table 3.4**

Sponsor	Research Centre	Subject	Status
EPRI	-	Brain tumours among children	Initial planning stage
New York State Dept. of Health	-	Study of childhood cancer and proximity to powerlines in New York State	Initial planning stage
Ontario Hydro	Toronto Sick Childrens Hospital	Study of childhood leukaemia and proximity to powerlines in Ontario	Underway
Cancer Control Agency of British-Columbia et al	-	Study of EMF exposures experienced by all Canadian children whose leukaemia is in remission	Initial planning stage
Hydro Quebec, Ontario Hydro, Electricite de France	McGill University	Epidemiological study of incidence of cancer and EMF exposure among 150,000 electric utility workers	Commenced 1988

**Table 3.4**

Sponsor	Research Centre	Subject	Status
National Environmental Institute of Sweden	National Environ. Institute of Sweden	Cancer incidence and EMF exposure of populations living within 300m of power lines	Underway Target Completion 1992
National Institute of Occupational Health, Sweden	National Institute of Occupational Health, Sweden	(1) Leukaemia and brain tumour incidence and EMF exposure in workers exposed to EMF's. (2) Adverse pregnancies among wives of utility workers vs EMF and VDU exposure (3) 10 year programme following health of 700 newly employed electrical utility workers.	Underway Target Completion 1992 Planned Completion in 1995

**Table 3.4**

Sponsor	Research Centre	Subject	Status
CEGB, England	University of Oxford	Epidemiology of childhood cancers in the vicinity of powerlines, including EMF measurements.	Advanced Planning Stage
California Public Utilities Commission	Dept. of Health Services	Design and management of research projects to be identified as a result of a 9 month study	Commenced May 1988

There is little doubt that by 1991-1992 when the results of most of the studies identified in Table 3.4 are available, it should be possible to answer with much greater certainty the questions.

. "Do power lines fields represent a hazard to health?"

. "If so, what is the extent of the risk?"

. "If the risk is significant what should be done to mitigate this risk?"

However, as a final comment, one should not be misled into thinking that epidemiology will provide all the answers. Dr. W. Ross Adey, in a criticism of the British CEGB study, stated that the Board should also examine the effect of electromagnetic fields on cells cultured in vitro (Adey, 1988).

### **3.4 Biological Studies**

Biological Studies fall into four categories:

- outdoor studies involving livestock
- laboratory studies involving small mammals
- laboratory studies involving human volunteers
- cell culture and exposure studies

Because of the difficulties and expense there have been very few controlled experiments which have examined the effects of electromagnetic fields on livestock, and particularly livestock reproduction which is usually of most concern.

In contrast there have been large numbers of studies involving exposure of laboratory animals, usually rats and mice, to electromagnetic fields and a comprehensive review of all such work would be a major undertaking well beyond the scope of this investigation. However the main findings of this work are identified.

A number of human exposure studies are also discussed.

In the case of cell culture and exposure studies the writer has depended mainly on the reports of expert groups, such as WHO, and on direct discussions with a small number of national laboratories in different countries.

### **3.4.1 Livestock Studies**

The main livestock studies identified are summarised in Table 3.5

**Table 3.5 Electromagnetic Field Exposures and Livestock**

Reference	Subject	Conclusion
Ware (1974)	Investigation of reports of ill-effects to cattle in vicinity of 765kV line	No evidence to substantiate claims
Busby et al (1974)	Field Survey of farmer experience with 765kV transmission lines	No adverse effects due to transmission lines
Williams & Beiler (1979)	6 year study of 55 dairy farms near 765kV lines in Ohio	No long term effects on milk production.
Amsutz and Miller (1980)	Comprehensive survey of cattle, sheep, pigs and horses on 11 farms near a 765kV line in Indiana.	Incidence of calf mortality and birth defects increased. No evidence that health, behaviour, or performance of animals were affected.

**Table 3.5**

Reference	Subject	Conclusion
Algers et al (1981)	Investigation of alleged connection between long term exposure of dairy cattle to 400kV lines in Sweden and fertility disturbances	A considerably decreased fertility during the grazing season was observed.
Hennichs (1982)	A survey of 106 farms throughout Sweden concerning cattle fertility and exposure to 400kV lines	Exposed cattle did not have decreased fertility.
Rogers et al (1982)	The behaviour of cattle under a prototype 1100kV line which was alternately energised and de-energised was observed by time lapse photography over 5 summer seasons.	The animals showed no reluctance to drink or graze beneath the line.
Mahmound & Zimmerman (1983)	A study of behaviour and performance of pigs purposely raised beneath a 345kV line in Iowa. This was a case control study.	No effects were observed on body weight, carcass quality, behaviour, or feed intake.



**Table 3.5**

Reference	Subject	Conclusion
Martin et al (1983)	A statistical study of dairy farms close to and distant from a $\pm$ 400kV DC line in Minnesota	No differences were found in milk production, calving intervals, rate of culling for reproductive problems, and incidence of abortions.
Mahmoud & Zimmerman (1984)	Follow up to the pig study reported in 1983 by the same researchers, re 345kV line in Iowa	No effect observed on pregnancy rate, frequency of birth defects, or weight gain of young.
Algers and Hennichs (1985)	A nationwide survey of 106 dairy herds in Sweden exposed to 400kV power lines.	No overall reduction in fertility among the exposed cows.
Algers and Hultgren (1986)	A case control study to investigate the influence on reproductive performance in cattle of continuous exposure to 400kV transmission lines for a long period (typically 120 days)	None of the parameters reflecting ovarian activity, estrous, pregnancy, and fetal viability were found to be influenced by the exposure

**Table 3.5**

Reference	Subject	Conclusion
Raleigh (1986, 1987)	A 3 year study to assess effect on beef cattle and crops of a $\pm$ 500kV DC transmission line, a case-control study.	By the end of year 2 no significant differences in growth, health, or reproduction were found between the two groups of cattle.

The studies detailed in Table 3.5 give a clean bill of health to power lines as far as livestock is concerned. The only two adverse reports were reversed by later research. Some of the major work in this area has been undertaken by the U.S. Department of Energy through the Bonneville Power Administration (Rogers et al, 1982; Raleigh, 1986, 1987)

### 3.4.2 Laboratory Studies

The main attraction of employing laboratory animals in evaluating the possible effect on human beings of some agent, be it physical, chemical or biological, is that one can expose a small animal to much larger amounts of the agent than one could safely expose a human volunteer even where one could be found. It is also possible to increase doses to lethal levels and continue sub-lethal doses through several generations. Hence in the case of exposure of laboratory animals to electromagnetic fields, researchers are seeking to identify those field strengths which produce some measurable or observable change. In this way it should be possible to offer some guidance on safe and unsafe levels of exposure for human beings.

One of the difficulties with exposure tests involving electromagnetic fields is that at high voltages there is a danger of electrocution, at high frequencies there is a danger of overheating, and at high field strengths there is the danger of inducing high body currents which may cause shocks or overheating. Researchers must be careful therefore to ensure that the test exposures do not produce 'thermal' effects.

Possible effects of electromagnetic fields can also be investigated by exposing preparations of cells or tissues to the fields (in vitro studies). Such studies are employed to assist in evaluating or developing possible mechanisms for interactions between EMF and cell biology. They are also useful in identifying agents which can damage chromosomes within the cell and so lead to

abnormal developments, particularly in pregnancy. However damage demonstrated in cell exposure studies does not necessarily mean that humans under similar exposures will be also damaged, but it would show a need for further tests employing laboratory animals. Conversely where no cell damage is detected such results offer reassurance to humans subject to similar or lower exposures.

Much of the cellular research reported is primarily aimed at increasing our knowledge of how cells function and communicate. It is not generally undertaken with a view to explaining or discovering the biological effects of power transmission lines. Hence for this part of the report it was decided to concentrate on three main sources of information:

- . The World Health Organisation Report on Magnetic Fields (WHO, 1987).
- . The New York State Power Lines Project, Final Report of Scientific Advisory Panel (Ahlbom et al, 1987)
- . Discussions the writer had with researchers during the course of this study.

The WHO report is the most comprehensive, authoritative and objective review of the scientific literature up to and including 1986. The New York State Power Lines Project report deals with the results of a number of research projects specifically designed to help answer some of the major questions being asked by the scientific community about the health effects of power transmission lines. The discussions the writer had with the World Health Organisation (Switzerland), the National Radiological Protection Board (UK), the National Institute of Occupational Health (Sweden), the Electric Power Research Institute (USA), the National Institute

of Health (Italy) and with other researchers helped put the reported research findings in context and identified some of the essential work remaining to be done.

### **3.4.3 The World Health Organisation**

#### **(A) WHO Report on Magnetic Fields**

The WHO report on magnetic fields (WHO, 1987) identified 20 behavioural studies involving laboratory animals and 7 involving human volunteers. In all cases the subject was exposed to alternating magnetic fields of varying strengths and frequency. These studies were nearly equally divided between positive findings of behavioural effects and no observations of effects. In the case of the human volunteer studies, no perception of field or behavioural changes were noted with 50-60Hz magnetic fields up to 2.12 millitesla in strength. The WHO highlighted the importance that animal behaviour should not be affected by extraneous factors during the tests such as vibration or audible noise from the magnetic coils. In later discussions with NRPB it was found that researchers there go to great-lengths-to-avoid-any-outside-disturbance to their test animals.

Concerning the physiological effects of alternating magnetic fields WHO detailed 25 animals studies and 3 involving human volunteers. While most of the animal studies produced some effect on cells and tissues WHO noted that the maximum current densities induced in the animals were greater than the endogenous currents normally present in the animal body. Hence it is possible that some thermal effects were contributing to the effects observed. The WHO highlighted one study of human volunteers (Sander et al, 1982) where a 4 hour

exposure to a 50Hz, 5 millitesla field produced no changes in over a dozen clinical measures of the bodies response to stress. A field strength of 5 millitesla is about 250 times greater than that which one would experience directly under a 500kV transmission line.

A further 30 studies involving the exposure of a variety of human and animal cell cultures to electromagnetic fields were assessed by the WHO. Most of these studies indicated some effect, although on many occasions the effects were in opposite directions.

In summary WHO concluded that low frequency magnetic fields did produce three proven effects:

- (1) the induction of electric potentials in a body,
- (2) magnetophosphene induction (visual sensations) at 15 - 60Hz field strengths of 2 to 10 millitesla,
- (3) cellular and tissue changes when induced current density exceeds 10mA/sq. m.

WHO added that in order to produce significant alterations in the development, physiology, and behaviour of intact higher organisms (e.g. people) induced current densities must exceed 10mA/sq. m.

**B) Meeting 24th August 1988 with Dr. P.J. Waight, WHO Geneva**

Dr.Waight was the Secretary to the WHO/IRPA Task Group which had been responsible for the WHO Environmental Health Criteria Report 69 on Magnetic Fields, which was published about a year ago. When asked specifically about the findings of this report and whether he would modify these or any of the report's conclusions in the light of the many publications in this area in the last 12 months

Waight stated emphatically that he would change nothing. In fact he saw no need to revise Report 69 for another 6 years until the next scheduled revision.

Concerning the literature since Report 69 was published, Waight's views of this were:

- . Some epidemiological studies have shown an effect at power frequencies, while other studies have shown no effect.
- . Many of the 'positive' studies have been criticised for being poorly designed and poorly executed.
- . Many of the 'negative' studies do not appear in the literature simply because they show no effect which the researchers or the publishers consider worth publishing.
- . No one has put forward a satisfactory physiological explanation for the association between electromagnetic fields and cancer.
- . No dose-effect relationship can be established.
- . Even the recent Savitz paper (Savitz 1988) gave contradictory dose-effect information. The correlation found by Savitz was strongest where magnetic fields were of low strength and not where magnetic fields were stronger.
- . However there were a large number of studies showing a positive connection and hence one cannot come to a firm or dogmatic conclusion. More time is needed to study the problem and exchange information.
- . If there is a risk then it is an extremely small risk. Meanwhile it is not justified to prohibit power-line construction, change configurations (of power lines), or for utilities to spend money (on minimising magnetic fields from overhead power-lines).

Waight was critical of the quality of much epidemiological research and had coined the aphorism "in any epidemiological study, the credibility of the result is inversely proportional to the level of statistical sophistication of the analysis required to demonstrate the effect".

Waight who had worked in radiation protection in Canada prior to working with WHO drew some comparisons between ionising radiation and non-ionising radiation in respect of health effects:

- . Damage to the person was noticed within one year of the discovery \* of ionising radiation. Electricity has been transmitted by cables for over 100 years and the recent suggestions of adverse health effects from power lines have not been confirmed.
- . In ordinary (ionising) radiation protection there is a clear dose-effect relationship. No such relationship has been demonstrated with EMFs.
- . Where there is no absolute safe minimum level of exposure, as is generally agreed in the case with ionising radiation, regulatory authorities optimise the cost of the risk against the value of the benefit. If the benefit outweighs the risk then the risk is considered acceptable.

\*[Roentgen discovered x-rays in December 1895. By 1896 investigators reported loss of hair and skin ulcerations. The first cancer victim from over-exposure to x-rays was Friedrich Claussen in 1900 who had exposed his hands to x-rays over 1000 times in public demonstrations in Berlin and who died of generalized carcinomatosis after amputation of his right arm. (Hamilton and Hardy, 1974).]



It may be possible to reduce the treatment of non-ionising radiation to a similar basis. If there is a risk, the risk is small. The cost of the risk is therefore small and the benefit from radio, television, electricity etc. far out-weighs the risk.

In regard to the proposed WHO programme for non-ionising radiation, WHO plan as follows:

1. To revise Document No. 16, which deals with radio-frequency and microwaves, and publish a new document in 1990.
2. To then examine optical radiation, including lasers, uV exposures, and the effects of visible light. In due course a new Environmental Health Criteria document would be issued.
3. As mentioned earlier electromagnetic fields would be re-examined in six or seven years time.

#### 3.4.4. The New York State Power Lines Project

In 1980, following public concern at proposed 765kV power lines in New York State, a \$5 million project was set up under the administration of the New York State Department of Health. This project represented one of the most important, comprehensive, and totally impartial effort to establish the relationship if any between electromagnetic fields generated by high voltage power transmission lines and human health. Under the guidance of a broadly based and international scientific panel, projects were invited from leading laboratories and researchers in seven study areas: genetics and reproduction; cell and organ culture and development; in vivo animals physiology; animal and human neurobiology; animal and human behaviour; controlled exposure of human volunteers; epidemiological studies of human populations. From 164 proposals, 16 research contracts were awarded. Where any adverse effects were observed, experimental techniques were subject to further independent assessment and where appropriate the research was duplicated in another laboratory.

In July, 1987 the final report of the Scientific Advisory Panel was published (Ahlbom et al, 1987). The main findings in each of the areas under investigation were:

**A) Genetics and Reproduction****(i) Chromosomes**

Three research groups investigated the effects of electromagnetic fields on cell chromosomes. No damaging effects were found:

- . Brookhaven Laboratory (Carsten, 1987) found no damage in chromosomes derived from blood samples of chronically exposed mice.
- . University of Maryland (Cohen, 1987a) found no effect on chromosomes from human lymphocytes exposed in vitro.
- . University of Utah (Livingston, 1987) found no effect on chromosomes from human lymphocytes and hamster ovary cells.

The Scientific Panel concluded that it was unlikely that electromagnetic fields damage human chromosomes.

**(ii) Cell Cycle (Generation) Time**

No exposure effects were observed by the Brookhaven Laboratory on lymphocyte cell cycle time, nor by the Utah group on the cell cycle time of hamster ovary cells.

**(iii) Teratogenesis, Growth, Development and Fertility**

Brookhaven Laboratory investigated the effects of exposure on two strains of mice. Exposures were 20-24 hours per day for the animals' lifetime and through a number of generations. Numerous measures of health and fecundity were made of the mice populations. No adverse effects were found.

The Scientific Panel concluded that the study was reassuring even if it did not constitute definitive proof that humans are similarly not vulnerably to these fields.

**B) Cell and Organ Culture and Development**

Cell culture techniques enable homogeneous populations of a single cell type to be exposed to toxicological and environmental influences, and can be a valuable tool in studying the influence of electromagnetic fields. In the work they sponsored in this area the Scientific Panel restricted researchers to 60Hz fields up to one order of magnitude higher strength than could be reasonably expected in the general environment. Cells investigated were taken from bone, the nervous system, the eye and from the canine and human immune systems.

In canine immune system studies (Winters, 1987) no effect on DNA, RNA, or protein synthesis was found as a result of exposure. While some transient changes were found in human lymphocytes the Scientific Panel concluded that immunological functions were not perturbed by the electromagnetic field. However the Panel cautioned against drawing any strong conclusions from the work by Winters on immune response.

Cultured cells from the skull of a fetal rat (Rodan, 1987) also showed no exposure-induced alterations in DNA synthesis.

Studies on the effect of electromagnetic fields on human and rabbit corneal cell cultures showed no differences in viability or in protein synthesis when compared to unexposed cells (Basu, 1987).

Although not an objective of the original New York State research protocol Winters with a co-worker Phillips utilised the equipment funded by the Project to conduct studies of the growth of cancer cells in soft agar (a common culture medium). This additional study led Winters and Phillips to claim that magnetic fields stimulated the growth of cancer cells (Phillips et al, 1986). These claims, published prior to the completion of the New York Power Lines Project report aroused much public concern. The response of the Scientific Panel was to engage two independent consultants to assess Winters' experiment design and examine the laboratory data. In addition another laboratory was engaged to replicate the 'cancer growth' experiment (Cohen, 1987b) and samples of the tumour cells were sent to yet a third laboratory to check that the strain being employed had not mutated or changed in some way.

The end result of all this effort was that the Scientific Panel totally rejected the results of Winters' cancer growth study on the basis that the conclusions were not supported by the facts and that the experiment could not be replicated. Phillips however still stands by his results, despite the fact that his work was discredited by the Power Lines Project report.

### **C) Neurobiology and Behaviour**

#### **(1) Brain and Neuronal Development**

The effects of EMF on the development of rat cerebellum was investigated (Gona, 1987). Field strengths up to 100kV/m and 1 millitesla were employed. Pregnant rats were exposed from days 5-20 of pregnancy. Autopsies were carried out on exposed and

control pups 1, 2, and 3 weeks after birth. Numerous parameters of body and brain development were measured and assessed. No significant differences existed between the exposed and control groups.

#### **(ii) Sensation and Perception**

Human subjects were exposed to electric fields between 0 and 16kV/m; and to magnetic fields of between 0 and 40 microtesla in order to determine the levels at which the fields were perceived (Graham, 1987). The electric field was detected at or above 9kV/m. The magnetic field was not detectable.

The subjects also undertook a wide variety of cognitive tasks. Some effects were noticed with the exposed group performing marginally better in some tasks and marginally poorer in other tasks than the control group. The magnitude of the reported effects was considered extremely small in the opinion of the Scientific Panel.

The effect of electromagnetic fields on the ability of mice to detect sensation was a complementary study (Ossenkopp, 1987). The conclusions of this study were:

- . mice detect the presence of an electric field at 9kV/m,
- . EMF can reduce the pain threshold,
- . EMF does not radically alter cognitive activities.

#### **(iii) Cellular Neuroscience and Calcium**

No changes were found in calcium efflux from spinal cord neuron-muscle cultures when exposed to 100 microtesla, 30kV/m fields (Gundersen, 1987)

**(iv) Biological Rhythms**

The major result of a study (Sulzman, 1987) involving monkeys and the effects of power line fields on circadian-related systems was to suggest that long term exposure to electromagnetic fields can shift or induce a lag in intrinsic rhythms. While these shifts can become chronic, the effect of EMF on melatonin synthesis appears within minutes but the effect is transient.

**(v) Seizures and Neurochemistry**

The mortality of rats in which seizures are chemically induced is reduced by exposure to EMF (Ossenkopp, 1987). No mechanism for this effect could be determined. This result does not suggest that EMF is a hazard to people with seizure disorders. The beneficial effect warrants further study, in the opinion of the Scientific Panel.

Exposure of macaques (short-tailed monkeys) to EMF for the purpose of measuring brain activity and neurochemistry showed no significant affects (Wolpaw, 1987). No changes in neuropathology were observed in the brains of 5 autopsied animals.

**(vi) Learning and Memory**

Three projects were conducted into the effects of EMF exposure and learning:

- . Effects of brief exposures on adult rat learning (Thomas, 1987).
- . Effects of prenatal exposure on adult rat learning (Salzinger, 1987).

The efficacy of EMF as a learning cue for mice (Ossenkopp, 1987).

The Scientific Advisory Panel concluded that EMFs of power line intensity do not influence even the most complex operant schedules during adult learning situations. However interactions between the geomagnetic field and a 60Hz magnetic field can influence behaviour, but the effect is transient and reversible. Prenatal exposure does seem to slow the learning process in rats.

**D) Epidemiological Studies**

The epidemiological studies commissioned by the New York Power Lines Project (Savitz , 1987b; and Stevens, 1987) have been discussed earlier in Section 3.3.1.



### 3.4.5 National Radiological Protection Board, England

About 5% of the activity of the UK National Radiological Protection Board is devoted to work on non-ionising radiation, equivalent to about 12 man years effort per year.

NRPB's initial research interest was in the effects of microwaves (2.45GHz) on sperm production, reproduction, the induction of lethal mutations in male germ cells and also in microwave effects on animal behaviour. Later, this work was extended to include studies of the effects of extremely low frequency (ELF) electric fields on calcium exchange in brain tissue and this work is still in progress. The work of other researchers in these and other related areas, such as the effects of EMF on the blood-brain barrier, was kept under constant review.

In this work field strength power densities in the range 1-500 watts/sq.m were employed which corresponded to specific energy absorption rates (SARs) in the tissues of the animals exposed of 0.05-25 watts per kg. These exposures are much higher than the limits recommended for the public by IRPA/INRC which limit SAR to 0.08 watts per kg at frequencies above 10 MHz.

In a review by NRPB (Blackwell and Saunders, 1986) of research by other laboratories working in this area NRPB found no changes that could not be attributed to some consequence of the heating effect of the radiation. Only when brain temperatures in the subjects were raised by several deg.C (e.g. to 40 C) or when body core temperatures were raised by 1 C or 2 C was there evidence of changes in chemical transfer across the blood-brain barrier in the

one case, and animal behaviour in the other. The blood-brain barrier provides a means whereby a correct balance of electrolytes and macromolecules is maintained in the extra-cellular fluid of the brain.

The interest relating to calcium ion exchange in brain tissue stems from work in the early 1980's by Adey and others (Adey et al, 1982) which indicated that exposure of cats to 16Hz amplitude modulated 450MHz radiation depressed that rate of efflux of radioactive 'tagged' calcium ion from the cortex. Calcium ions play a vital role in many physiological and metabolic processes, particularly in nervous tissue, and changes in calcium ion concentration induced experimentally in laboratory animals have been associated with behavioural changes (Myers & Ross, 1981). However NRPB are not convinced that exposure to micro-waves or radio-waves can induce such behavioural changes.

Studies on mice at NRPB have indicated no chromosome changes, no effects on male germ cells, and no mutagenesis following exposure to microwaves (Saunders et al, 1988).

NRPB have also investigated the mutagenic (dominant lethal) effect of 50 Hz electric fields, up to 20kV/m on mice and found no effects. This work is in the process of being published.

More recently NRPB has begun to examine the long term influence of 50Hz magnetic fields on the development of the embryo and fetus of mice, because of concerns about the effect of exposing pregnant women in magnetic resonance diagnostic systems. A specially designed water cooled magnet capable of generating a 200 Gauss

(20 millitesla) 50Hz field is being employed. The results of the study should be complete in about 18 months. NRPB feel that many experiments involving magnetic fields and animal behaviour do not take sufficient account of the need to ensure the magnet is effectively silenced and that controls are exposed to virtually identical conditions. There was also a need for a consistent and rigorous approach to the statistical analysis of results.

Currently further work is underway examining the effects on animal growth and on the amount of stress hormone released due to exposure (of rats) to 20 millitesla magnetic fields at 50Hz. The preliminary results indicate that this field has no effect on growth or stress level.

Work is also currently underway at NRPB exposing bone marrow stem cells from CBA mice to 50Hz magnetic fields. CBA mice are genetically prone to leukaemia induction by ionising radiation but have a low spontaneous background. The work, which is nearing completion, involves an examination of the bone marrow cells for their proliferative capacity and for chromosome aberrations in oncology. No adverse effects have been found, so far.

NRPB is critical of a number of brain studies where the brain cells are not kept in as 'live' a condition as possible during experiments. The relevance of many studies employing what is effectively dead brain tissue (from chickens) is seriously questioned. NRPB is currently studying calcium efflux from rat brain slices maintained in an oxygenated saline solution under electric fields of 5-100 Hz.

NRPB's view on the famous 'egg' study sponsored by the United States Navy (U.S. Navy, 1988) following Delgado's earlier findings (Delgado et al 1981, 1982) that chicken embryos exposed to pulsed magnetic fields showed morphological abnormalities, was that the results were inconclusive. In the Navy study six laboratories endeavoured to repeat Delgado's experiment. Two laboratories reported a positive finding while four found nothing. Later one of the 'positive' laboratories failed to reproduce its earlier results.

[It should be mentioned here that other researchers have interpreted the U.S. Navy study results differently].

NRPB are about to commence work to look at the effect of static and 50Hz magnetic fields on DNA repair after or during exposure to agents such as ionising radiation which are known to damage chromosomes. Work is also being carried out at the University of Oxford (with NRPB support) on the possible effects of static magnetic fields on reducing or accelerating metabolic reactions.

NRPB have recommended limits of exposure to time varying magnetic fields encountered in magnetic resonance systems which are based on limiting induced electric current density; static fields generated by these systems are limited to 2.5 tesla at present because there is good evidence that exposure up to about this level is without adverse effect. WHO (1987) indicate the possibility of adverse effects above 5 tesla. It is also recommended that pregnant women are not exposed during the first trimester because of uncertainty about effects on the embryo and

fetus. All these limits are concerned with avoiding possible non-thermal effects. NRPB are investigating, or are encouraging the investigations of, other possible non-thermal effects.

Concerning some of the theories proposed by others to explain possible non-thermal health effects, NRPB's views were:

A. The Melatonin Hypothesis

i.e Electro-magnetic fields reduce the production of melatonin from the pineal gland. Melatonin levels are disturbed and consequently circadian rhythms are upset leading to adverse biological consequences.

Daylight suppresses melatonin levels. Concern arose from proposals to introduce 'full spectrum lighting' - essentially artificial sunlight - into the work-place and the effect this would have on behaviour, performance, and general well being. The energy in sunlight and in many forms of artificial lighting is many orders of magnitude greater than the energy radiated from power lines. Any contribution of ~~power fields to the suppression of melatonin levels is~~ considered infinitesimal compared to other natural and artificial influences. It is difficult to take such a hypothesis seriously. For example it is known that uVa light suppresses T-cell lymphocyte production (part of the bodies defense mechanism). However the power of sunlight, typically 20,000 lux, is vastly greater than that of fluorescent light (600 lux). It cannot be seen how EMF fields from power lines can have an impact on T-cell lymphocyte production.

B. Cyclotron Resonance

i.e. The superimposition of a low frequency magnetic field, such as might be produced by power lines, upon the earth's static magnetic field applies an electro-motive force to cations normally present at cell wall boundaries. The normal movement of these cations (such as calcium ions) across cell walls is disturbed and accelerated. As the cations' normal movements are said to represent a means of communication among cells, abnormal and accelerated movements convey erroneous messages. The latter can be said to explain cancer especially where the life form is at a stage of rapid cell division, e.g. in a growing child.

The NRPB consider that the energies imparted to ionic materials by this mechanism are significantly less than those imparted by Brownian movement via normal temperature effects. Essentially any additional movement generated by cyclotron resonance is swamped by the prevailing rapid movement of ions and molecules. It is possible that electro-magnetic fields could interfere with free radicals produced by enzyme reactions. There may be a tenuous link to DNA production. However there is no data or evidence available to enable one to quantify the risk of these events occurring. NRPB are planning to look at cyclotron resonance in the future and devise some appropriate experiments. They are sceptical at this time that there exist frequency 'windows' which enable weak electro-magnetic fields to penetrate and damage cell membranes.

### 3.4.6 Electric Power Research Institute, California

#### A) Current Work

EPRI has been sponsoring biological studies since 1973, mostly involving animal exposure to electric fields. Funding was at levels of \$2 million/year until 1988 when funding was increased to \$4.3 million/year, reflecting public concern.

EPRI is funding a number of laboratory studies to investigate the mechanisms of certain biological effects, as well as a project to determine whether magnetic fields cause cancer in animals. The possible biological effects of EMF are said to be effects on behaviour, cellular membrane function, and biological rhythms. This work is managed by Dr. Rafferty.

Discussions with Rafferty were centred mainly on the results of a recent animal studies workshop and on possible mechanisms which may explain how EMF affects cells.

EPRI had sponsored research at Batelle-Pacific-Northwest Laboratories in which the effect of exposure to strong electric fields on the frequency of congenital defects in the offspring of female rats was monitored. The rats were exposed throughout their lives to the electric fields. Field strengths up to 130kV/metre were employed. This study has now been completed and is about to be published. It completes ten years of EPRI - sponsored studies on the effects of strong electric fields on reproduction in pigs and rats. The final studies, involving the exposure of female rats from conception, mating and 20 days of gestation yielded the following key results (EPRI, 1988).

The litters of the offspring of these female rats showed the following percentage abnormalities:

- 5.0% abnormal in the sham exposed (background) group.
- 3.6% abnormal in the 10kV/m group.
- 9.8% abnormal in the 65kV/m group.
- 5.0% abnormal in the 130kV/m group.

These differences were not considered statistically significant. The study group concluded that although extrapolation of animal studies to humans always involves uncertainty, it did not appear that electric fields even three times higher than those a man might be exposed to directly under high voltage transmission lines are linked to birth defects and development malformations in humans. This work was reviewed by a standing advisory committee of distinguished scientists knowledgeable in the EMF-biology area. The committee concluded that no association between electric field exposure and teratological effects was indicated, and that no new electric field teratology studies should be undertaken by EPRI.

Currently a new teratology study is being planned using high strength magnetic fields. This work, also to be undertaken at Batelle Northwest, will involve exposure of pregnant female rats to three levels of magnetic field strength up to 10 gauss. Teratologists would ideally like to see field strengths to a level capable of affecting at least 50% of the fetuses. There is no known level of magnetic field which will produce an effect of this magnitude.



## **B) Future Work**

EPRI's objectives are to identify reproducible biological end points (i.e. phenomena), and relate these to field strength and frequency. For example there is an apparent change in gene expression in DNA when subject to EMF. Messenger RNA may also be affected. This is an area EPRI is exploring through a research contract with Columbia University. The principal investigators of this project are Dr. Reba Goodman and Dr. Ann Henderson. This work will involve exposure of fruit-fly cells and human cells to low frequency electromagnetic fields.

Related research at Columbia University is also being supported by the Office of Naval Research. The effect of EMF on tumour development in rats is also to be studied by Dr. Sol Michaelson and Dr. Shin-tsu Lu at the University of Rochester. A neurobiology study is at the 'literature research' stage. As is discussed later a major programme of work on animal studies is under consideration. There is also the major Batelle Northwest study on examining the teratogenic effects of magnetic fields which has been discussed. EPRI is also planning research on ion transport in membranes and on the "cyclotron resonance" model.

## **C) Workshop on Animal Studies, Carmel, California, (July 1988)**

This was attended by some 50 people including all leading U.S. researchers plus several European experts, including Professor Knave from Sweden. The purpose of the workshop was to provide guidelines for developing a new research programme concerning the influence of EMF on the promotion of cancer in animals and simple organisms. The workshop reviewed the current EPRI programme,

considered the value of various new courses of research, and concluded by devising a number of key experiments which could be completed within a 2 year time-frame ideally. Dr. Rafferty was the workshop organiser. Dr. Marvin Goldman of the University of California at Davis chaired the workshop.

The workshop recommended a wide ranging series of projects for the proposed research programme. This programme would cost around \$3.5 million and could be completed within three years. Rafferty provided some background to some of the projects in this programme:

Leukaemia: This is not a cancer promotion experiment. There would be no initiation of cancer by a carcinogen. The study would involve exposing a strain of mice genetically disposed to developing leukaemia.

Skin Cancer: This would be a whole animal study to see if magnetic fields promoted cancer that was already induced by some other agent. Here skin cancer would be studied.

NTP Test: This is to test electromagnetic field radiation in a standard screening experiment developed by the National Toxicology Programme (NTP) which evaluates toxic agents with respect to their carcinogenic potential.

Liver Cancer: This is similar to the skin cancer project, except that liver cancer would be studied.

Tumour Growth: Here cancer cells would be transplanted into a new animal and the effects of EMF observed.

Brain Cancer: This study is on a rodent strain predisposed to develop brain cancer and is concerned with the effects of EMF on the incidence and growth of tumours. [Cancer progresses through three stages - initiation, promotion, and finally growth].

Membrane Effects: This study proposal has been stimulated in part, by Dr. W. Ross Adey's work which indicated that EMF may affect communication between cells. Adey's work suggests that low level EMF affects the functions of channels and material transfers through the channels in the cell membrane (Adey, 1987). According to Rafferty, Adey focuses on communication between cells but doesn't explain how or why the various field parameters (strength, frequency, etc) are important.

**D) EPRI View on Mechanisms**

Dr. Rafferty's view is that nearly all of the evidence which supports the hypothesis that EMF affects cancers and tumours comes from epidemiological studies of human populations. Savitz in the New York Power Lines Study looked at electromagnetic fields and other environmental agents and found that magnetic fields gave the only positive connection. Savitz work suggests that there may be a public health problem, but there is very little laboratory data to back this up. All the tests now being proposed have magnetic fields as a priority. Several teratology studies involving electric fields have shown no positive connection. Earlier Dr. Sagan was willing to be quoted in his statement that "electric fields have a clear bill of health".

Dr. Rafferty felt that the underlying reason for the search for a mechanism to explain the possible role of EMF in promoting cancer is simply that, in view of the very marginal epidemiological evidence that EMF is carcinogenic, some rational biological mechanism must be identified to provide support for the position. If no mechanism can be demonstrated then one must remain sceptical about conclusions drawn from the epidemiological studies undertaken up to now.

Dr. Sagan considered that as there had been demonstrated effects of EMF on animals and cells there must be some mechanism, although at this stage there is no definitive knowledge of the mechanism involved.

Rafferty could not accept that Ross Adey's "interference with cell membrane communication paths" or the "melatonin suppression hypothesis" were mechanisms per se. These were higher order effects. Dr. Sagan was sure that EMF did not affect cell nuclei - no mutagenesis was involved. Adey's view was that there were frequency and intensity windows in the cell membrane that affected calcium efflux which in turn played a key role in cell communication.

The "cyclotron resonance model" provided a possible explanation, according to Dr. Rafferty. However while this model predicts frequency dependent biological effects it is quite inadequate thermodynamically. Normal biological functions require more energy and have longer response times than the cyclotron resonance model seems to provide. In cyclotron resonance a charged particle passing through a magnetic field will be diverted by the magnetic field. If energy is transferred to the charged particle as it could do under the influence of an alternating field then it will move in a circular or helical path. The greater the velocity and hence the energy of the charge then the greater will be the radius of the path followed. In the cyclotron the presence of a strong DC magnetic field in conjunction with an alternating electric field is a necessary condition for changing the kinetic energy of charged particles. In cyclotron resonance the DC magnetic field is provided by the earth's own magnetic field. Hence, according to the mechanism, charged biological ions can pass through channels in cell membranes under the influence of a superimposed low frequency magnetic field where under normal circumstances this wouldn't happen to the same extent. The motion of the charged

particles is believed to be helical and related to the helixes of protein structure. The radius of the path is of the same order as the pores in the cell membrane channels.

Experiments to measure change in concentration of ions across cell membranes does provide some evidence that such changes occur at a cyclotron frequency that depends on the ion being measured and the strength of the magnetic fields involved. However Rafferty repeated that this movement of ions was impossible to explain by the thermodynamics of the cyclotron resonance theory. [The laws of thermodynamics are immutable - the explanation must be found in some modification to the cyclotron resonance theory - T.McM].

The more important of the magnetic fields is the geomagnetic field whose strength is 20-60 microtesla. This strength is harnessed by charged particles by electro-magnetic induction via the superimposed AC field. Whether the ion follows a helical or circular path depends on the angles of the two fields. The thermodynamic problem is that the normal Brownian movement of ions and molecules - the random motion present in all liquids as a result of its temperature - should swamp the additional component of movement generated by cyclotron resonance. In Rafferty's words this dilemma "represents an opportunity for the advancement of science".

The connection, if there is one, between cyclotron resonance and cancer follows the following hypothesis:

1. The normal changes in ion concentration across a cell membrane represent a flow of information.
2. Low frequency magnetic fields effect a disturbance to ionic concentrations.

3. Hence there is a change in the flow of information
4. Such changes may send "error" signals to cells - and so induce cancer, or promote cancer, or accelerate the growth of cancer.

Another possible mechanism under consideration by Dr. Rafferty is the direct coupling of magnetic fields with magnetic material in the body - such as magnetite. While the amounts, sizes, and location of micron-sized magnetite magnets in the body are still matters open to speculation it is believed such things exist and that they may have a biological function. In certain bacteria, in birds, and in some kinds of fish there is strong evidence that magnetite plays a key role, particularly in direction finding. While AC magnetic fields must be of high strength to remove magnetic material, they are able to influence movement at much lower field strengths. EPRI is planning to sponsor research soon on the structure of magnetic sense organs in fish at Caltech (Dr. Kirschvink).

#### **E) Credibility of EPRI Work**

EPRI work is highly regarded in the scientific community. EPRI rejects totally criticisms of its work made by Becker.

All EMF related EPRI sponsored work is reviewed by a consultative Board of Scientific Advisers, some 15 strong. This Board examines all project proposals and the results of all completed projects. It operates through three committees which deal with epidemiological studies, experimental assessment, and basic sciences. The Chairman is Dr. Gilbert Omenn, Dean of the School of Public Health at the University of Washington in Seattle. The

membership of the Board is drawn entirely from outside EPRI and mostly comprises University professors plus one private consultant and an eminent researcher from Batelle Northwest Laboratory (Dr. T.S. Tenforde).

The various programmes of research developed by EPRI are also reviewed by a group of "Utility Advisors" drawn from the electrical utilities which fund EPRI.

EPRI do not undertake EMF research per se at their Palo Alto headquarters. All research is done by universities and outside laboratories. EPRI expects and indeed encourages publication of research findings in responsible journals where papers are subject to peer review.



#### **3.4.7 National Institute of Occupational Health, Solna, Sweden**

The subject of possible mechanisms of electromagnetic field health effects was discussed with Professor Knave at a meeting in August 1988.

Knave gave some credence to the melatonin hypothesis - that the reduction in melatonin production from the pineal gland arising from exposures to EMF affected growth and cell reproduction in children. He was however interested in the proposed Bonneville Power Authority study of melatonin production in sheep under various exposures. Knave mentioned that those who medically treat depression with bright light do not appear to rate an additional cancer risk very high. While melatonin may not be a major factor in cancer incidence Knave's view was that cancer was multifactorial and that reduced melatonin levels could be one of a number of elements that taken together could induce a cancer.

Knave was not impressed by the Adey-cell membrane hypotheses - that electromagnetic fields disturbed the molecular signals being transferred across the cell interface and so induced cancer by wrongly directed messenger cells. He also referred to recent work (Albert et al, 1987) which had failed to replicate Adey's original findings on calcium ion 'windows' - particular frequencies which particularly affected calcium ion transfer across the blood-brain boundary.

Knave was much more interested in Liboff's cyclotron resonance theory (Liboff et al, 1987) - that alternating magnetic fields superimposed upon the earth's static field impart significant additional movement and energy to ionic material and in some way this disturbance leads to abnormal cell growth.

It was Knave's view that if electromagnetic fields induce or promote cancer then it is by a mechanism that is quite new and different from known mechanisms for proven carcinogenic materials. Therefore if it is confirmed that EMFs cause cancer and if a mechanism can be determined then such a discovery would affect our understanding of life and cell biology in a most fundamental way.

#### 4. Positions and Opinions on Electromagnetic Fields and Health

The extensive literature on EMF-health effects is surveyed very regularly by many individual researchers. However the conclusions and opinions expressed in these reviews are generally those of the individuals themselves. In order to obtain a more objective and balanced assessment of the mass of epidemiological and biological research papers many national legislative bodies, national and international scientific and medical advisory groups, electrical utilities, and electrical research institutes undertake or commission studies of the literature. Upon the results of these studies the various organisations have generally based their policy or 'position' statements.

In this section the conclusions of various such commissioned studies are summarised. Unless otherwise stated a quotation or extract from the actual report or statement is given. For convenience the studies and statements are grouped into the following categories:

- . International Organisations
- . National Organisations
- . State and Provincial Organisations
- . Electrical Utilities
- . Individual Researchers

For balance some of the statements and opinions of those researchers who do not share many of views expressed by the 'establishment', as represented by the first 4 of the above groups, are also included. Where possible the statement or the opinion expressed was obtained verbatim from recorded television programmes or public enquiries.

#### 4.1 International Organisations

##### 4.1.1 World Health Organisation

###### Non-ionizing Radiation Protection (WHO, 1982)

"The data available at the present time can be summarized as follows:

- (a) experimental studies show that electric fields of intensity up to 20kV/m and magnetic fields of intensity up to 240 amps/m, i.e. 0.3 millitesla, whether individually or in combination, do not constitute a danger to health;
- (b) under the experimental conditions used, stress symptoms are not a primary effect of electric or magnetic fields;
- (c) as far as epidemiological long-term studies of exposure to electric fields are concerned, the observation of workers in high-voltage substations and on power lines have failed to show any adverse health effects;
- (d) no mechanism of action is known whereby power frequency fields can produce direct effects on living organisms;
- (e) no specific symptoms have so far been detected in humans as a consequence of exposure to these fields;
- (f) electric and magnetic fields caused by transmission systems up to system voltages of 420kV do not constitute a danger to human health; and
- (g) it can be assumed, on the basis of experience to date, that this is also true for 800 kV systems"

Extremely Low Frequency Fields (WHO, 1984)

"It is not possible from present knowledge to make a definitive statement about the safety or hazard associated with long-term exposure to sinusoidal electric fields in the range of 1 - 10 kV/m. In the absence of specific evidence of particular risk or disease syndromes associated with such exposure, and in view of experimental findings on the biological effects of exposure, it is recommended that efforts be made to limit exposure, particularly for members of the general population, to levels as low as can be reasonably achieved."

Magnetic Fields (WHO, 1987)

"... assuming worst-case conditions, it is possible to calculate, at least within one order of magnitude, the magnetic flux density that would produce potentially hazardous current densities in tissues. The following statements can be made on induced current sinusoidal homogeneous fields, which produce biological effects from whole-body exposure:

- (a) Between 1 and 10 mA/sq.m (induced by magnetic fields above 0.5 - 5 mT at 50/60 Hz, or 10 - 100 mT at 3 Hz), minor biological effects have been reported.
- (b) Between 10 and 100 mA/sq.m (above 5 - 50 mT at 50/60 Hz or 100 - 1000 mT at 3 Hz), there are well established effects, including visual and nervous system effects. Facilitation of bone fracture reunion has been reported".

"Several recent epidemiological reports present preliminary data indicative of an increase in the incidence of cancer among children, adults, and occupational groups. In other epidemiological studies in the USA, no apparent increases in genetic defects or abnormal pregnancies were reported. The studies that show an excess of cancers in children and adults suggest an association with exposure to very weak (0.1 to 1 microtesla) 50 or 60 Hz magnetic fields that are of a magnitude commonly found in the environment. These associations cannot be satisfactorily explained by the available theoretical basis for carcinogenesis by ELF electromagnetic fields. The preliminary nature of the epidemiological evidence, and the relatively small increment in reported incidence, suggest that, although these epidemiological data cannot be dismissed, there must be considerable further study before they can be accepted.

From the available data on human exposure to time-varying magnetic fields, it can be concluded that induced current densities below 10 mA/sq.m have not been shown to produce any significant biological effects".

#### 4.1.2 United Nations Economic & Social Council

##### Biological Effects of HV Electric Fields (UNESCO, 1987a)

"It may be noted that, in the present state of research and of the findings which have been made, it is now possible to draw an entirely reassuring conclusion concerning the effects of electric fields. This concurs with the conclusion reached by the experts assembled by the World Health Organization, who consider that the strongest electric fields created near conductors of very high voltage transmission structures are without danger for man.

In any case, field strengths found around structures carrying 400 KV - which is at present the highest voltage used in western Europe and will probably remain so for a long time to come - can in no way be a cause of concern to the public".

..... extract from Report of Group of Experts, July 1987.

#### 4.1.3 International Radiation Protection Association

##### Guidelines on Limits of Exposure to electromagnetic Fields at 50/60 HZ (IRPA, 1987)

"Exposure limits for ELF electric and magnetic fields:

These limits apply to human exposure to electric and magnetic fields at frequencies of 50 or 60 Hz, and may be applied to the power frequency of 16.6 Hz. These limits should not be applied to ELF frequencies above 60Hz.

General public - Electric Fields:

The general public should not be exposed to rms unperturbed\* electric field strengths above 10 kV/m.

\* unperturbed means field strength measured in the absence of anyone or anything in the field - TMCM.

Short term exposure (hours per day) to 10 kV/m is acceptable, however continuous exposure (24 hours per day) should be limited to rms fields less than 5 kV/m. Buildings intended for the use of members of the general public or for habitation should be erected only in a location where the unperturbed electric field strength outside the building 1.5 m above the ground and 1.5 m from the building does not exceed 5 kV/m. The same restriction applies to open space areas where members of the general public might reasonably be expected to spend a substantial part of the day, such as recreational areas, sport facilities, meeting grounds and similar.

General Public:- Magnetic fields:

The general public should not be exposed to rms magnetic field strengths above 0.2 millitesla (200 microtesla)".

Carcinogenic Potential of Extremely Low Frequency Fields

(Repacholi, 1988)

"One of the major arguments against there being an association between electromagnetic radiation exposure and increased incidence of cancer, is the fact that laboratory studies have not identified a mechanism by which these radiations at 50/60Hz could either induce or promote cancer.



One of the only theories to suggest a mechanism by which 50/60Hz or microwave fields could promote cancer has had evidence published against one of its basic premises, that microwaves, modulated to 16Hz, do not alter the efflux of calcium ions from brain tissue.

In the final analysis, if an increased cancer risk is definitely found to be associated with chronic low-level exposure to 50/60Hz fields, the risk must be quantitated so that a risk-benefit analysis can be completed.

To date, chronic low-level exposure to 50/60Hz fields has not been established to increase the risk of contracting cancer. If it is established in the future, it would in all likelihood be an extremely weak carcinogen."

.... extract from a paper delivered at a Workshop that preceded the International Radiation Protection Association Congress held in Sydney, 10-17 April, 1988.

#### **4.2 National Organisations**

##### **4.2.1 Canada**

- **Report of Working Group on Electromagnetic Fields**  
(Health and Welfare Canada, 1988)

"Based on reviews of current knowledge by groups of acknowledged experts and more recent publications, the Working Group reached the following consensus conclusions:

- . There is evidence from epidemiological studies suggesting that exposure to magnetic fields may be associated with increased incidence of cancer, primarily leukaemia and brain cancer, in children.
- . There is some evidence that occupational exposures to electromagnetic fields increase rates of some cancers, in particular brain tumours and leukaemia.
- . By epidemiological standards the reported increased risks seem to be low to moderate.
- . Experimental studies on carcinogenesis in animals are insufficient to evaluate potential carcinogenicity.
- . In vitro assays have failed to demonstrate any genetic damage.

Considering that additional research effort should be undertaken in Canada to resolve whether there is association between exposure to 60 Hz electric and magnetic fields and an increased risk of cancer, it is recommended that:

- . the Department of Health and Welfare intensify its participation in its on-going research, and
- . an Advisory Committee be established to advise on research."

#### 4.2.2 Federal Republic of Germany

##### . Electric and Magnetic Fields at Power Frequencies

(Hauf, 1982), Institute of Electropathology, Freiburg.

"... experimental studies show that electric fields of intensity up to 20 kV/m and magnetic fields of intensity up to (300 microtesla), whether individually or in combination, do not constitute a danger to health".

#### 4.2.3 Italy

##### . Biological Effects of Exposure to Electric Fields at 50Hz

(Malaguti et al, 1980), Electrical Research Centre, Trieste.

"The results of epidemiological research performed with humans, as well as the experimental data on animals available in the literature, do not unequivocally demonstrate the existence of a pathology from electrical fields".

#### 4.2.4 Norway

##### . Biological Effects of Electric and Magnetic Fields

(Waskaas, 1981) State Institute of Radiation Hygiene, Osteras.

"This literature study shows that we still know very little about the interaction between extremely low-frequency electromagnetic fields and living organisms. But, so far, nobody has proved that any hazardous biological effects are

caused by the electric and magnetic fields that the general public may be exposed to under 400kV transmission lines (less than 9 kV/m ...)"

#### 4.2.5 Sweden

##### . Advice to Government on Electromagnetic Fields

(Knave, 1988), National Institute of Occupational Health, Solna.

"The results of Swedish and other investigations and research are not enough to warrant the establishing of threshold limits for exposure to electromagnetic fields. There are some indications of adverse health effects. On the cancer side these indications do exist. Because occupational exposures are orders of magnitude greater than the residential exposures that have been implicated in epidemiological studies it is vital that the occupational group studies are supported by Government as well as well-designed general population studies, such as that being undertaken by Ahlbom.

When the results of the various Swedish studies are completed in 1992 more definitive recommendations can be made. I will give an answer in five years"... B. Knave.

..... from National Energy Administration Report, 1988.

#### 4.2.6 Switzerland

. Environmental Effects of HV Electric Fields (UNESCO, 1987b)

..... Govt. of Switzerland to Economic Commission for  
Europe, July, 1987.

"Having regard to the currents transmitted, to the 50 Hz frequency, and to the conductor spacing, electro-magnetic fields are so weak that their effect may be regarded from the outset as negligible. Despite that, there has been research on the effect of magnetic fields created by power lines on human beings and animals.

A great many persons and animals of both sexes and various ages have been subjected for varying lengths of time by Swiss and foreign research institutes to the electric and magnetic fields found beneath very high voltage lines (380 kV), and various physiological tests were carried out. As no harmful effect on the organism could be found, the field strengths were considerably increased, in some instances to more than three times the values encountered in practice. Even then, the physiological data monitored remained unaltered, with few exceptions. No effect could be found that threatened the health, and far less the life of human beings or animals.

To date, there is no indication from any of the research and investigations to support the conclusion that the fields produced by the power transmission and distribution equipment of electricity undertakings have harmful effects on human

well-being or health status. There are no grounds for any apprehension even when transformer stations are incorporated in dwellings or when high voltage lines pass over dwellings".

#### 4.2.7 United Kingdom

- Advice on the Protection of Workers and Members of the Public from the Possible Hazards of Electric and Magnetic Fields

(NRPB, 1986)

"For exposures of members of the public in their homes and gardens, or in the workplace when exposure to electromagnetic fields is not part of a person's occupation, the Board considers that even mild perceptible effects should be avoided whenever possible".

Guideline values for residential areas below which it is unnecessary to consider occupancy and shielding factors are (at 50Hz)

electric field strength	2600 volts per metre
magnetic field strength	0.176 millitesla.

[It should be noted that these recommendations will be superseded in forthcoming advice (NRPB, 1988c) q.v.]

- Response of Medical Research Council to Questions ... concerning Human Exposures to Electromagnetic Fields

(MRC, 1987)

"The Group considered that epidemiological studies purporting to demonstrate a correlation between exposure and the incidence of neoplasms and congenital abnormalities were inconclusive, except where substantial rises in core

temperature had been induced in experimental animals. Increases of more than 1 deg. C maternal core temperature in lower animals increased the incidence of congenital anomalies. Also there was no convincing experimental evidence demonstrating that exposure to electromagnetic fields, at field strengths normally encountered, directly caused neoplasms or congenital abnormalities; some experiments in which such a link had been suggested were likely to have involved substantial (i.e. more than 1 deg.C) increases in temperature of the cells under investigation. The Group agreed that the published literature should be kept under constant review and that if any convincing evidence arose that exposure did cause neoplasms or congenital abnormalities, this evidence should be used as a basis for recommendations."

Health Issues in the Siting of a Low Frequency  
Transmission Mast

(Dennis, 1988)

"In 1982 and again in 1986, NRPB published consultative documents containing proposals for limits on the exposure of workers and members of the public to electromagnetic fields at power, radio and microwave frequencies. The comments received in response to those documents, including advice from the Medical Research Council, will be used in the preparation of definite advice later in 1988 or early in 1989. Suffice to say that this advice will possibly be less restrictive than in the proposals in the 1986 consultative document as regards occupational exposure".

"All significant effects of a hazardous nature that have been observed in mammals require exposures at levels at which heating occurs and to an extent that raises the body temperature. In the case of humans this will require rates of energy absorption in excess of 1 or 2 W/kg. At the IRPA/INRC guideline levels for public exposure in the frequency range 100 kHz to 1 MHz the average rate of energy absorption is about 10,000 times less than the harmful thresholds.

It seems improbable that there is any risk of cancer or birth defects at exposure levels corresponding to the IRPA/INRC public exposure limits and, if there is, it is likely to be much less than from the carcinogenic agents already present in the environment, e.g., the natural ionising radiation background".

. Standard Response Letter to Local Authorities following publicity concerning Dr. Savitz report linking powerlines to cancer

(NRPB, 1988a)

"Most observers are treating the results of the Savitz study with caution because of the statistical weaknesses and also because no known biological mechanism can explain a connection between magnetic fields and the induction or promotion of cancer. It is, however, known that magnetic fields can produce some effects in cells and in animals and that some of these effects may be of relevance. It is a very difficult research area and many experiments have shown no



effects. On the whole, the evidence for an association between magnetic fields and cancer is too tenuous to be conclusive but too consistent to be ignored".

.... extract.

Circular to Electricity Generating Boards following  
publicity concerning the electromagnetic field - health  
effects problem

(NRPB, 1988b)

"The evidence for an association between childhood cancer and magnetic fields from power lines is weak. The magnitude of the risk if it is real is such that it should not give undue concern to individuals, although it is proper that the possible risk is taken seriously by appropriate authorities. Magnetic fields near many domestic appliances may be at least an order of magnitude greater than those which appear to be of concern. This fact and other important social and economic factors suggest that, although at this time the requirement of some planning authorities for development-free zones of twenty to thirty metres about the centre of power line corridors may be a prudent policy, it would be difficult to justify the need for a corridor of this or any other width on the basis of the available scientific evidence".

..... extract.

Note on Levels proposed in the Consultative

Document (NRPB, 1986) for continuous Exposure of the  
Public (NRPB, 1988c)

The levels proposed in the (NRPB, 1986) consultative document for continuous exposure of the public will be superseded in the forthcoming advice which will give the following reference levels at 50 Hz for both workers and members of the public:

electric field	12,280 V/m		
magnetic field	1630 A/m	(2 millitesla)	

These are levels below which there is no danger of electric shock or burn from induced electric currents in the body or from contact with large ungrounded objects in the fields. The advice is aimed solely at preventing these known hazards and the hazard of overheating of the body at higher frequencies. Exposures above the reference levels will be allowed provided that it can be demonstrated that these hazards can be prevented. As regards possible athermal effects, the advice will say that there is at present insufficient data either to make a health risk assessment (in any quantified sense) or even to determine whether there is a potential hazard to health from such effects".

#### 4.2.8 United States

- American national standards safety levels with respect to human exposure to radio frequency electromagnetic fields (ANSI, 1982)

The American National Standards Institute (ANSI) has produced a review of literature (ANSI, 1982) and screened only those reports that produced positive findings, were reproducible, and supplied adequate dosimetric information. Evaluations were made of these selected reports in terms of whether or not the biological effects constituted a hazard to health. Behaviour in experimental animals was found to be the most sensitive indicator of an adverse health effect (e.g. convulsion activity, work stoppage, work decrement, decreased endurance, perception of the exposing field and aversion behaviour (Justesen, 1979)). On the basis of their review, ANSI concluded that acute (less than 1 hour) exposure to electromagnetic energy that is deposited in the whole body at an average SAR of less than 4 W/kg does not produce an adverse health effect in experimental animals. However, because prolonged exposure (days and weeks) may cause damage, a tenfold reduction in the permissible SAR (i.e. 0.4 W/kg) was invoked.

..... review taken from "Health Physics", 54: pp115-123, 1988

- High Power Voltage Lines ....Health and Safety Concerns (Dodge, 1984), Congressional Research Service, US Congress.

"At this time, it is premature to implicate all low-level, non-ionizing radiations in specific human health disorder. At the same time, in the absence of controlled

epidemiological and basic research, it is also premature to state unequivocally that there are no health risks from low-level, non-ionizing radiations. It can only be speculated that it is unlikely that such radiations will be implicated significantly in human health disorders".

. Biological and Human Health Effects of Extremely Low Frequency Electromagnetic Fields

(American Institute of Biological Sciences, 1985)

"ELF electric and magnetic fields can, at least in some frequency and intensity combinations and under certain circumstances, cause a variety of effects at any of several levels of biological organization of plants and animals or in vitro preparations. Additional research on coupling of living systems to ELF electric and magnetic fields, on mechanisms of interaction, and on responses of biological materials to such fields will be necessary to gain a more nearly complete understanding of the biological significance, if any, of interactions of these fields with living systems".  
(ELF: extreme low frequency).

. EMF and Health (EPRI, 1987)

The work continues and firm answers are elusive. The evidence for an association with cancer or any other disease is tenuous, but legitimate questions do remain. Leonard Sagan observes, "Although there is no scientific consensus in this area and the results linking magnetic fields to adverse health effects are weak, the fact that reputable studies even

suggest that such a link exist places a responsibility on EPRI and the industry to reduce the uncertainty and to put any risks that may exist into perspective".

#### 4.2.9 U.S.S.R.

. Environmental Effects of HV Electrical Fields (UNESCO, 1986)

.... Government of U.S.S.R. to Economic Commission for Europe, October, 1986.

Observations carried out on areas affected by 500 or 750kV overhead lines over a period of many years have shown that an electrical field that is within the limits set for such lines in the USSR has practically no harmful influence on the development of the flora and fauna in the area in question or in the surrounding neighbourhood.

### 4.3 State and Provincial Organisations

#### 4.3.1 Florida

. Biological Effects of 60Hz Power Transmission Lines  
(Florida, 1985)

"The Commission unanimously believes that the scientific information now available supports the conclusion that it is unlikely that 60-Hz electric and magnetic fields associated with high voltage transmissions lines has led, or can lead, to public health problems. However, some ambiguities in the currently available science precludes our categorically concluding that absolutely no public health problem exists.

Report of the Florida Electric and Magnetic Fields  
Scientific Advisory Panel (Florida, 1987)

"It is not possible from current knowledge to say with any confidence how safe or dangerous long term exposure to EMF might be. This uncertainty makes it difficult to establish a standard for existing transmission or distribution lines on the basis of protecting public health from a known hazard. To allow for a large measure of caution, and to protect public welfare, one might propose an interim standard (lasting no more than three years) for the regulation of new lines.

Proposed Rule on Electric and Magnetic Fields  
(Florida, May 1988)

"Although there is no conclusive evidence that there is any danger or hazard to public health or the environment at the levels of existing electric and magnetic fields found in Florida, there is sufficient scientific evidence to indicate that further research is needed before reaching a conclusion of no danger or potential danger to public health exists. Therefore, the Department enacts this chapter to maintain the status quo to the greatest extent practicable in regards to the exposure of the public and the environment to electric and magnetic fields and to minimize any increase in exposure."

#### 4.3.2 Michigan

- . The Effects of Electromagnetic Fields produced by High Voltage Transmission lines (Young, 1984), Michigan Legislative Science Office.

"The highest priority must be given to establishing a biological framework which will explain or discredit the reported effects of power frequency fields. Until then all the reported research results must be regarded as representing 'possible effects' even though the newest generation of extremely low frequency field research is free of the defects of earlier inquiries".

#### 4.3.3. Montana

- . Biological Effects of High Voltage AC Transmission Lines (Sheppard, 1983), Report to Montana Dept. of Natural Resources and Conservation.

"The foregoing review of research in laboratory animals and the few studies of humans leads to conclusion that pathophysiological effects in human beings exposed to 60-Hz electric fields at any field strength are unproven and speculative. Similarly, subtle effects on the nervous system that may alter mental state, disrupt normal body rhythmicity, alter libido, increase the frequency or severity of headaches, or lead to effects on digestion or other functions influenced by the central nervous system, are not demonstrated by the scientific research to date".

#### 4.3.4 New York

- . Is there a Need for the Commission to Reconsider its Decision to Allow an Electric Field of 1.6KV/m at the Edge of Rights-of-Way in New York, and should the Commission Now Consider Setting a Standard for Edge-of-Rights-of-Way Magnetic Field Strength?

(Eabry, 1983), New York Office of Environmental Planning.

"None of the research studies mentioned in this paper can be considered as a definitive demonstration that man-made electric or magnetic fields are hazardous to humans, neither can they be presumed harmless".

- . Biological Effects of Power Line Fields (Ahlbom et al, 1987)

.... New York State Power Lines Project, Final Report.

"The research program, supported by contributions assessed from all New York State electric utilities, provided support to 16 different research groups studying human, animal and isolated cell sensitivity to electric and magnetic fields. Most of the research studies reported no effects of concern. Of the few effects, some warrant further consideration.

No effects were found on reproduction, growth or development. Several studies showed no evidence of genetic or chromosomal damage that might lead to inherited effects or cause cancer. While most measurements of behaviour and brain function did not demonstrate changes, some did show changes that were small but consistent. Some of these appear to result from



changes in body rhythms, and might interfere with normal sleep patterns. There were also changes in pain responses and in the ability of rats to learn.

A more serious concern comes from a study of cancer in children suggesting that children with leukaemia and brain cancer are more likely to live in homes where there are elevated 60-Hz magnetic field levels than are children who do not have cancer. Although much more research is needed before the question whether the magnetic fields actual cause or promote cancer can be resolved, the basis for such an hypothesis is now established. At this time no risk assessments can be made because only four studies of this question have been made and the two which report an association are from the same geographic region. More research on cancer as a function of magnetic fields is needed, both in homes and for on-the-job exposure".

Adoption of a Number of Recommendations based on New York State Power Lines Project Final Report, including Evaluation of said Report by Dept. of Public Service - New York State.

(New York State, 1988), Dept. of Public Service.

"The Power Lines Project report contained findings of 17 studies of biological effects of electric and magnetic fields, and recommended additional research into several areas. It found no proof that electric and magnetic fields were hazards. It also concluded that the findings do not

readily translate into concrete regulatory recommendations on width of right-of-way, line heights, or location of lines near homes.

The Commission accepted the recommendation that the 350-foot right-of-way adopted on an interim basis in 1978 for a 765-kilovolt lines from the Quebec border to Utica should be continued on an interim basis, subject to further research findings. In its 1978 order, the Commission found that the electric field at the edge of the 350-foot right-of-way would be no greater than that at the edge of a typical 345-kilovolt right-of-way, a risk implicitly accepted by society over the decades of operation of 345-kilovolt lines."

#### 4.3.5 Ontario

. Health Effects of.... Electromagnetic Fields - a Review of Clinical and Epidemiological studies  
(Ontario Ministry of Health, 1987).

"The literature available to date on human health effects of exposure to ELF fields examines the incidence of cancer, adverse reproductive outcomes and physical and psychological general health effects. There is general agreement among scientific researchers that there are many ambiguities present in the current literature. Despite the amount of effort and the diversity of the questions examined in the literature, the results have failed to support a causal relationship between ELF field exposure and a variety of adverse health effects. This literature fails to provide conclusive or convincing evidence that there is a public health risk associated with ELF field."

#### 4.3.6 Virginia

##### Health Effects of High Voltage Transmission Lines

(Wasti, 1987), Virginia State Dept. of Health.

"The overall evidence from epidemiological and experimental studies available to date is still somewhat rarefied and incongruous, and does not unambiguously elicit exposure to electric and magnetic fields in the magnitude produced by high voltage transmission lines as a cause of cancer or any other significant deleterious effects in humans".

"Though [the Savitz study] represents improvements and refinements over previous studies, it suggests only a modest increment in risk, if any. It does not preclude the involvement of certain other etiological confounders, and in [my] own view falls far short of implicating electromagnetic fields".

#### 4.4 North American Power Utilities

##### 4.4.1 Bonneville Power Administration, U.S. Dept. of Energy

"Based on more than 20 years of research, the bulk of the scientific evidence indicates that typical exposure to electric fields such as produced by BPA transmission lines poses no health hazard. This conclusion is based on the results of many published scientific reviews of this research. This subject remains controversial, however, because some studies have found effects with uncertain biological significance. It is not possible

to conclude scientifically that there is zero risk associated with long-term electric field exposure. There is also renewed interest in magnetic fields. Studies in the 1960's and 1970's found no harmful effects of a-c magnetic fields. Because of this, and because of the small magnitude of a transmission line magnetic field, long-term effects were not of concern until recently. However, several recent reports have suggested a possible association between occupational and residential exposure to a-c magnetic fields and cancer. The evidence for such an association is weak, and studies are underway to obtain more definitive information on this subject.

Operating experience and research has not produced any evidence that the Pacific D-C Intertie has harmed people, animals, or plants. Also, a large body of research on air ions and d-c fields indicates that adverse effects are unlikely from d-c lines. Because of renewed interest in d-c lines, BPA has implemented an extensive program of electrical and agricultural studies at a research site along the  $\pm$  500-kV D-C Intertie in Oregon" (BPA, 1986).

#### **4.4.2 British Columbia Hydro**

"There is little doubt that transmission and distribution line levels of electromagnetic fields have some biological effects, however, there is still no conclusive evidence that they are a health hazard" (BC Hydro, 1988).

#### 4.4.3 Hydro-Quebec

"In June 1986, Hydro-Quebec adopted a plan of action designed to answer questions being raised with increasing frequency by the general public on the long-term effects of power lines on human and animal health."

"Since 1972 Hydro-Quebec has conducted and subsidized extensive research in the field. Similarly, international agencies such as the World Health Organization have studied these questions. At present, experts generally agree that short-term exposure to electric and magnetic fields created by power lines does not adversely affect human and animal health. Long-term effects have yet to be ascertained.

With this plan of action, Hydro-Quebec also intends to make an original, significant and scientifically valid contribution to research. To this end, it is engaging in fruitful exchanges with the international scientific community." (Hydro Quebec, 1988).

#### 4.4.4. Ontario Hydro

"Based on the evidence now available, the scientific community consensus is that a public health risk from exposure to any of these fields has not been established. If future research were to establish a link between electric and magnetic fields and health effects, it would be expected to present a very low level of risk to the public and employees.

There is at present no basis for Ontario Hydro to change existing practices for the generation, transmission, distribution and use of electricity.

We will continue the following actions to develop reliable information on which decisions can be made to ensure occupational and public safety:

- (a) Support continued health and safety research on an international level to ensure collection of the best possible data and their evaluation;
- (b) Identify the need for and initiate further research and, if appropriate, make changes to design and operating practices;
- (c) Remain abreast of developments by monitoring public and employee concerns, worldwide scientific and research programs, judicial decisions, regulatory requirements and operating practices and standards; and
- (d) Develop and maintain a communication program to provide information to all interested parties."

(Ontario Hydro, 1988).

#### **4.5 Individual Researchers**

##### **4.5.1 Those who are Convinced of Serious Health Hazards**

The advance of science and controversy among scientists often go hand in hand. Our improved understanding of the health effects of electromagnetic fields, although far from complete, must acknowledge the contribution of some of the pioneer workers in this area in bringing the matter to public attention (Marino et al, 1976; Becker and Marino, 1982; Wertheimer and Leeper, 1979).

These workers are still among the most outspoken critics of power utilities and are still firm in their belief that electromagnetic fields from power lines represent a serious health hazard.

At a U.S. Congressional Subcommittee Hearing (U.S. Congress, 1987) on EMF health effects Dr. Becker stated, among other things:

"Since then, there have been any number of studies, reviews of the literature, enormously expensive research projects, all of this at a lot of million dollars of public funding. And all of it, in my opinion, highly suspect. I know of no review of the literature - and that includes the New York State Power Lines Project panel report as well - I know of no review of the literature that is not biased and slanted and obviously written, in my opinion, with the intent to dis-inform the government".

"There have been multi-million dollar research projects set up to ostensibly evaluate the risks attendant to exposure to everything from extra low-frequency to microwave, and again these projects have either been delayed, obfuscated in their publication, or they were deliberately designed from the outset to yield negative results".

".....it is my opinion that non-ionizing electromagnetic radiation constitutes an environmental hazard to the population of this country that is considerably greater than any known chemical hazard that we have produced".

In March 1987 Professor Marino (Marino, 1987) was quoted in the "US News and World Report" as saying:

"We've reached a point that is comparable to the early 1960s, when air and water pollution was starting to be a concern. It is hard to realise that something as commonplace as the wires that deliver electricity to your home could be dangerous, but it is a very real threat".

In an earlier Australian television documentary on June 18, 1985 (ABC, 1985) Marino also stated:

"The idea that people would live directly under high voltage transmission lines is simply barbaric. There is certainly clear and convincing evidence that that practice ought to be stopped".

"The scientific evidence with regard to the health-risk aspect is clear and convincing and only likely to become more so".

On the same programme (ABC, 1985) Dr. Nancy Wertheimer stated:

"It's a public health problem".

Dr. Becker and Professor Marino have both appeared as expert witnesses for objectors at many hearings into proposed powerline construction projects across Canada and the United States. To date their main support in the scientific community comes from Dr. W. Ross Adey and Dr. J. L. Phillips..

Dr. Adey is a leading researcher in his particular specialist area - the biology and function of the cell membrane. All of the billions of cells that make up human tissue are enclosed in



a membrane made of fat molecules. Adey considers that electromagnetic fields can adversely affect the signals that normally pass through this membrane to initiate normal biological activity within the cells. Erroneous signals to the inside of the cell can promote cancer, it is hypothesised. The research of Adey is one of the strongest planks on which supporters of the position "EMFs cause cancer" base their case. Adey himself has no doubts as to the veracity of the membrane mechanism. At the US Congressional hearing, previously referred to (U.S. Congress, 1987), he stated:

"By the use of imposed electromagnetic fields in tissue to study the most fundamental aspects of cell functions, it has become clear that cell membranes are the site of joint actions of weak electromagnetic fields and chemical-stimulating molecules in initiating signals that pass to the cell interior".

"And what I want to point out is that this body of evidence - which comes as much from cancer research as it does from bio-electromagnetic-research---now stand as unequivocal evidence that there is an interrelationship between cancer promotion and electromagnetic field exposure".

Adey was scathing of the views of the scientific establishment who still contended that for EMF to be a health hazard it must first ionize or heat the tissue:

"There has been a persisting view amongst physical scientists with a background in ionizing radiation - including those from national laboratories with missions in nuclear physics and nuclear weapons - that non-ionizing electromagnetic fields are incapable of inducing biological effects other than by heating. In other words, this view has stoutly-but incorrectly - maintained that there are only two possible modes of tissue interactions with environmental fields. Either there must be ionization, or there must be tissue heating.

"This view - still widely preferred by these acolytes from another scientific age in consultant opinions to judicial and legislative bodies - overlooks a fundamental property of all living matter known as 'cooperativity'".

Dr. J.L. Phillips was the researcher who ran into problems with the New York State Power Lines Project by conducting research - unrequested by the Scientific Advisory Panel - into the growth of human colon tumour cells when exposed to electromagnetic fields. Although his claim - that such exposure greatly accelerated the growth of the cancer cells - was rejected by the Panel following a thorough investigation, Phillips stands by this work and reiterated his results at the Congressional Hearing (U.S. Congress, 1987):

"We have found in our laboratory experiments that human cancer cells exposed to 60-Hz electromagnetic fields, first, exhibit 2- to 24- fold greater growth of stem cells; that is, the initiated cells in the tumour population; secondly, exhibit increased expression of a growth-related

cellular protein on the surface of the cell. Thirdly, the cells exhibit greatly increased resistance to destruction by cells of the body's defense system; and, fourth, the changes that we observed are permanent".

He also stated:

"..... because the available scientific literature indicates that electromagnetic fields appear to serve as tumour promoters. This is something that both Drs. Adey and Becker have already mentioned. The question, therefore, is not whether 60-Hz electromagnetic fields cause cancer, but rather what is the extent to which such fields contribute to the development of clinical cancer?"

The strong views held by the group have not softened. As recently as 1st September 1988, Becker was quoted (Collings, 1988) as likening EMF to cigarette smoking:

"Another American, Dr. Robert O. Becker, author of The Body Electric and a leading authority on electromagnetic pollution, is less cautious.—He says—"we have evidence that man-made electromagnetic fields from power lines are far more productive of serious health effects than cigarette smoking.... I'm not saying cigarette smoking is not bad but evidence of an epidemiological nature shows that cancer in children as a result of power lines is of the same calibre as lung cancer from cigarettes".

Other views have been expressed, while not as strong or as alarmist of those of Becker, which do show a degree of growing concern over the EMF problem in some quarters of the U.S. Dept. of Energy and in the New York State Power Lines Project committee:

Dr. Imre Gyuk, programme manager in the U.S. Dept. of Energy's Biomagnetics Research Division was quoted recently as saying (Ross, 1988):

"I believe it is a potential health hazard. There are some tentative epidemiological studies and a lot of confounding variables, and a null hypothesis cannot be ruled out".

Dr. David Carpenter who co-ordinated the New York State Power Lines Project has become progressively more cautious in his statements concerning the findings of the Power Line Project. Carpenter is quoted (Ross, 1988) giving an opinion on the results of the Savitz study:

"The results imply that the problem is a pervasive one, in that it has less to do with high voltage lines and more to do with how we deliver electricity". In addition, Carpenter said that the findings of the Savitz study may not be unique to children: "I have a suspicion that if the proper adult study is done it could show similar results".

In connection with the 'cancerphobia' case in New York State, detailed in section 4.5.2. which follows, expert testimony on behalf of the plaintiffs (the landowners who are claiming that a 345kV transmission line will lower the resale value of their properties) was provided by Drs. Becker, Marino, and Phillips

and by three others Dr. Harris Busch, Dr. Marvin Chatkoff, and Dr. Lennart Tomenius. From information that has recently become available (Health and Safety, 1988c) it does not appear that much of the testimony is new.

Dr. Busch of the Department of Pharmacology at the Baylor College of Medicine in Houston, compares the calculated strength of magnetic field in the vicinity of the power line to those levels indicated by Wertheimer to be in the range of significant risk for the development of cancer. He states:

"Magnetic fields of 0.5mG (0.05 microtesla) or less present some small risk for cancer development. However, electromagnetic fields of 1.2mG (0.12 microtesla) and above increase the risk by almost 4-fold for childhood cancer and 2-fold for cancer in ages 19-54. Magnetic fields of greater than 2.5 mG (0.25 microtesla) produce 6.5-fold increases in relative risk in children living in homes after birth and near the time of cancer onset."

~~Dr. Chatkoff of the Department of Electrical Engineering at~~  
the University of Texas at San Antonio, deals with the likely electrical and magnetic field levels in the vicinity of the proposed 345kV line. He concludes:

"The large variation in fields for 345-kV lines demonstrates how sensitive the fields are to the design parameters. This variation is much less for the larger voltages, especially for the single circuit configurations in which the choices are limited."

Dr. Tomenius, of the National Institute of Environmental Medicine in Stockholm testifies that his own research has shown an increased incidence of cancer among children living near 200kV transmission lines where exposure to 50Hz magnetic fields inside the homes regularly exceeds 3mG (0.3 microtesla). He states:

"My result concerning an increased incidence of childhood cancers within 150m of 200kV lines leads me to expect the same results for the 345kV Marcy-South line. Of course, my result does not exclude that a relationship between increased magnetic field/closeness to high-voltage lines and an increased incidence of childhood cancer also might exist for a magnetic field less than 3mG (0.3 microtesla) or for dwellings at a larger distance than 150m."

The testimonies of Dr. Phillips and Dr. Marino had been presented previously at other forums. Dr. Phillips' material was part of his testimony in the Houston school case in 1986 (See section 5.5.A). He states:

"The state of the literature today is such that about 18 epidemiological studies find a relationship between (either residential or occupational) to low level magnetic fields and an increased incidence of cancer. Furthermore, cellular studies that have been performed, including my own, provide insight into the mechanisms by which the increased incidence of cancer can be explained."

Dr. Marino's expert testimony consists of a paper presented at an International Utility Symposium held in Toronto in September 1986. No information on Dr. Becker's testimony is available at this time.

#### 4.5.2 Those who are Not Convinced of Serious Health Hazards

Some of the statements in section 4.5.1. totally contradict the findings of other research which has found, among other things, no link whatsoever between cell exposure to EMF nor any of the damage to cell chromosomes which might herald cancer. The debate on the biological effects of power lines will reach new heights later this year when a "Battle of the Giants" takes place in Goshen, New York. There some of the leading international figures will appear as expert witnesses, on the one hand, for the New York Power Authority and on the other hand, for landowners claiming damages because ".....the Power Authority, by creating a 'cancerphobia' corridor, has destroyed the market value of land in and around that corridor". The corridor in question relates to lands acquired to build a single circuit 345kV line. By deriving an acceptable threshold limit of magnetic field strength of 0.05 microtesla based on estimates by Wertheimer, the landowners have estimated the width of the affected corridor to be 2400ft.

The New York Power Authority went to great lengths to ensure the 'independence' of their witnesses and avoided any who had become too closely associated with the utility viewpoint in the past. To demonstrate that there are still many knowledgeable

individuals in responsible positions and not beholding to electrical utilities for research funds, who would not agree with the views of Drs. Adey, Becker, Marino et al, their identities are listed here. Extracts from the "expert reports" that are required to be filed prior to the litigation are also given.

- A) **S. A. Aaronson, MD**, Laboratory of Cellular and Molecular Biology, National Cancer Institute, Bethesda, Md.

Dr. Aaronson is an expert on genetics. Among the points made by him in his testimony are the following (Aaronson, 1988):

"The overwhelming body of scientific evidence in cellular genetics indicates that electric and/or magnetic fields are not a source of genetic damage to the organism".

"The pattern of effects of electric and/or magnetic fields on normal cell proliferation in tissue culture is one of inconsistency and non-reproducibility. There is no scientific basis to support the hypothesis that normal cells can be transformed as a result of exposure to power frequency electric and/or magnetic fields".

- B) **R. S. Bockman, MD PhD**, Department of Medicine, Cornell University Medical College, New York City.

Dr. Bockman has made a special study of the effects of EMF on the endocrine and immune systems. He makes a number of points, including (Bockman, 1988):



"EMF fields experienced directly under high voltage AC power lines are just at the threshold of perception for most animals and man under ideal conditions, i.e., low wind and low humidity.

"EMF field strengths several times greater than perception limit levels may cause an initial arousal (awareness) response. However, this response fades rapidly and the animals habituate to such fields. Chronic exposure to such fields causes no identifiable abnormality in adrenal gland function and there is no physiological or neuroendocrine evidence of stress.

"There is no scientific basis to believe that EMF fields can alter intra-cellular calcium levels or that calcium acts as a transducer of EMF effects on nerve, endocrine or immune cells.

"There is no persuasive scientific evidence that EMF fields have any significant biological effects on circadian rhythms of critical pituitary hormones. EMF fields have not been shown to cause stress or to adversely affect even complex endocrine systems such as those involved in reproduction, growth and development.

"The scientific literature does not indicate that the immune system is altered by exposure to EMF fields such as those generated by high voltage AC power lines".

C) **R. K. Boutwell**, PhD, Department of Oncology, University of Wisconsin, Madison.

Dr. Boutwell is a cancer specialist. Among the points he makes is the statement (Boutwell, 1988):

"No convincing evidence exists for adverse effects of power frequency electric and magnetic fields on cellular DNA, the sine qua non of initiation".

Concerning recent work on ornithine decarboxylase (ODC) research by Byus and Adey in which the latter had reported that EMF stimulated the production of this enzyme which ultimately can affect cell growth and differentiation and so promote cancer, Boutwell had this to say:

"The increase in ODC activity ranges upward from about 200-fold within 5 hours after exposure to a cancer promoter (e.g., TPA). The essential role of ODC in tumour promotion has been firmly established in the scientific literature. Cancers of humans as well as laboratory animals exhibit elevated levels of ODC; the cancer cells have lost the ability to control the activity of the enzyme. Byus, Pieper, and Adey proposed (Byus et al, 1987) that exposure to 60Hz electromagnetic fields may act as a tumour promoter because the fields caused an elevation of ODC activity. However, the changes in ODC activity that they reported are simply not indicative of the changes previously described for cancer promotion.

"In summary, my review of the scientific literature leads me to conclude that there is no scientific basis for the assertion that power frequency electric and/or magnetic fields are either cancer initiators or promoters".

D) **B. A. Egan MD**, Pediatrics and Physiology, State University of New York at Buffalo.

Dr. Egan specialises on the subject of reproduction and birth defects. He has reservations about some of Dr. Marino's original work on animal exposure to EMF (Egan, 1988):

"These studies have major deficiencies in design and analysis. More important, each has internal inconsistency of the reported effects, the signature of inadequate experiments... [Further] systematic, well-controlled investigations into reproductive effects of electric fields have been unable to document any adverse reproductive effects".

Concerning Delgados work on the teratogenic effects of EMF exposure on chicken embryos (eggs). Egan makes the point:

"The results show wide, unexplained variation in the control embryos, a 'window' of effect, not a dose response effect, and a disregard for usual statistical methods. Most importantly, the studies were not conducted at frequencies associated with electric power transmission. Four independent attempts to replicate teratogenic effects on chick embryos have all failed".

Egan concludes:

"The data are substantial, and I can conclude with confidence that electric and magnetic fields associated with electric power generation, transmission and use have had no ill effects on reproduction or prenatal

development. Moreover, an extensive research effort has not demonstrated any scientifically-based potential for such ill effects".

**E) L. F. Sinks, MD.** Division of Cancer Prevention and Control, National Cancer Institute, Bethesda, Md.

Dr. Sinks has 25 years experience investigating childhood cancer. Following a review of recent literature he comes to the following conclusions (Sinks, 1988):

"There is no scientific basis upon which to conclude that genetic damage results from exposure to power-frequency electric and magnetic fields".

"There is no valid scientific reason to believe power frequency electric and magnetic fields cause a pathological disturbance in the immune system".

"While there have been a number of epidemiology studies examining the possible association between electric and magnetic fields and childhood cancer, the results of these studies are very inconsistent. Some report an association, others do not. There are a number of recognized problems with these studies, including surrogate determination of electric and/or magnetic fields by the use of wire coding, biased and uncontrolled designs, inadequate controls, and residential mobility. The epidemiology studies as a whole do not, in my opinion, establish a relationship between power frequency electric and magnetic fields and childhood cancer".

F) H.S. Terrace, PhD, Columbia University, Ithaca, N.Y.

Dr. Terrace is a specialist in animal and human behavioural studies. In his conclusions on the ability to detect EMF he states (Terrace, 1988):

"The results of experiments performed on the detectability of power frequency electric and magnetic fields indicate that such fields can be sensed by some species under certain conditions. Sensitivity to such fields should, however, be regarded as borderline as compared to sensitivity to stimuli from the more familiar sensory modalities as sight, hearing, smell, taste and touch.... Attempts to determine the detectability of power-frequency magnetic fields directly have uniformly failed to obtain persuasive evidence that such fields are detectable by animal and human subjects".

"A representative sample of the relevant literature indicates that prenatal exposure of pregnant females to power frequency electric fields has no influence, either adverse or beneficial, on the behaviour of their offspring.

"The few positive findings that have reported an influence of power frequency electric field on circadian rhythms (in impoverished environments) have yet to be replicated. Even if they are, such influences would not appear to have any discernible, much less, adverse effects on behaviour".

- G) **Margaret A. Tucker, MD**, Environmental Epidemiology Branch,  
National Cancer Institute, National Institutes of Health,  
Bethesda, Md.

Dr. Tucker's speciality is epidemiology. Among other things she discusses the Savitz study (Savitz, 1987b) and comments (Tucker, 1988):

"There are some problems with the Savitz study, which the author himself discussed in his report. The most important of these is the low rate of the study subjects (the percentage of study subjects willing to participate), particularly the controls".

"In the childhood residential cancer studies there is no consistency in the level of risks either between studies or within studies, nor is there consistency in the pattern of risk within the studies. There is no convincing evidence of increasing risk with increasing exposure. Finally, there is no significant risk shown with actual measured electric or magnetic fields within the residences".

## 5. Aspects of Particular Importance to Ireland

### 5.1 Childhood Leukaemia in Ireland:

A major report into the incidence of childhood leukaemia in Ireland, its trends and geographical distribution was commissioned by the Department of Health (Daly et al, 1986). One of the objectives of this report was to determine if there was an increased incidence of childhood leukaemia along the east coast. To this end the incidence and mortality rates for childhood leukaemia were examined over 5 areas of the Republic:

- 1) District Electoral Divisions and Electoral Wards (DED's) with a coastal boundary on the east coast.
- 2) Urban and Rural Districts (UD/RD) with an east coast boundary excluding those areas covered in (1).
- 3) DEDs along the south coast.
- 4) UD/RDs along the south coast excluding areas covered in (3).
- 5) The remainder of the country.

Data were collected and validated for 273 deaths in the age group, 0-14 in the 12 years 1971-1982. Incidence data comprised 436 cases diagnosed for the same age group over a 10 year period 1974-1983.

The incidence of acute lymphoid leukaemia averaged 31 per million (children aged 0-14) per annum. This incidence falls within the widely reported 30-35 per million typical of white children in Europe and North America.

The authors concluded that

"During the total study period no excess of mortality or incidence was apparent on either the east or south coasts of the country and distribution of high rates was

quite random over the country as a whole. The fact that there were more areas with no cases in the west of Ireland than elsewhere may be a reflection of population density."

To illustrate the uniform mortality and incidence rates for acute lymphoid mortality (A.L.L.) some data for some larger population centres are set out in Table 5.1. It should be noted that one of the reasons given by the researchers for selecting this tumour for their study was that its induction period in children is relatively short, and its incidence might therefore reflect possible health consequences of levels of ionising radiation in the Irish Sea.

**Table 5.1      Incidence and Mortality in Children from A.L.L.**

-      Total Cases      -

Incidence :    over period 1974 - 1983

Mortality :    over period 1971 - 1982

---

Area	Incidence		Mortality	
	observed	expected	observed	expected
Dublin Co. Borough	39	43.2	26	28.3
North Co. Dublin	17	14.7	3	7.8
South Co. Dublin	28	28.3	13	16.0
Cork CB/RD & Cobh RD.	17	19.2	13	11.5
Limerick CB & No.1 RD	11	8.8	9	5.3
Galway MB & RD	8	5.9	3	3.4

---

The incidence and mortality rates showed an annual variation from about 20 to 40 per million (incidence) and from 12 to 22 per million (mortality), but neither adverse nor favourable trends over the period studied.



## 5.2 Electric Power Production in Ireland

Over the period 1962 to 1987 electrical energy production in Ireland increased nearly five fold:

**Table 5.2**      **Electric Energy Production in Ireland**

<u>Year</u>	<u>GWhr</u>
-----	
1962	2597
1970	5520
1980	10299
1987	12491
-----	

Sources: (Eurostat, 1988; ESB, 1988a)

However by European terms Ireland's per capita production of electricity is still relatively low (Table 5.3).

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**Table 5.3      Per Capita Electricity Production in Europe (1986)**


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<b>Country</b>	<b>Total Production (GWhr)</b>	<b>Production per capita (MWh/person)</b>
<hr/>		
Belgium	58676	6.0
Denmark	30720	6.0
Fed. Rep. Germany	408266	6.7
France	363155	6.5
Ireland	12652	3.6
Italy	192330	3.4
Netherlands	67158	4.6
United Kingdom	301088	5.3
EUR 12	1612343	5.0

---

Source: (Eurostat, 1988)

Electricity production per unit area is an indicator of the geographic intensity of electricity transmission, distribution and use. It is therefore also an indicator of electromagnetic field exposure. Table 5.4 offers an interesting inter-European comparison.

**Table 5.4      Intensity of Electricity Production.**

Country	Area	Electrical Production
	(sq. km)	(MWh/sq.km)
Belgium	30500	1924
Denmark	43100	713
Fed. Rep.Germany	248700	1642
France	549100	661
Ireland	70300	180
Italy	301300	638
Netherlands	41785	1607
United Kingdom	244100	1233
EUR 12	2260680	713

While electricity production per unit area is not a perfect surrogate for electromagnetic field exposure of a population there is little doubt that the density of overhead transmission lines is much lower in Ireland than in many other European countries.

### 5.3 Legal Position of ESB in Relation to the Issue

ESB discourages, as far as possible, residential building within 22m of the centreline of 220 kV power transmission lines. However ESB has no legal powers to prevent such building. When planning permission is granted for a dwelling close to a transmission line, and where no reasonable alternative site is available to the developer, ESB will compensate the developer for sterilising the appropriate area along the route of the line in return for an easement. This, in effect, gives ESB right-of-way over the area concerned in the sense that residential building is prohibited by the terms of the easement. The concept of 'right-of-way' is therefore adopted where it is appropriate to do so.

#### 5.4 Electromagnetic Fields Exposures & Standards

The strength of an electric field in the neighbourhood of a high voltage transmission line is a function of the height and geometry of the transmission line and its voltage. The electric field is not affected significantly by the electrical load being transmitted by the line. In contrast the magnetic field is a function of the electrical current flowing in the line and is related to the load being carried. In estimating the maximum strength of the magnetic field it is therefore necessary to consider the situation when the transmission line is fully loaded. Typical strengths of electric and magnetic fields in the vicinity of fully loaded high voltage transmission lines are set out in Table 5.5 for voltages from 110 kV to 1100 kV.

It should be noted that, strictly speaking, references to magnetic field strength should be in terms of amps per metre. The units 'microtesla' relate to magnetic flux density. However when one is concerned mainly with magnetic fields in air, magnetic fields strengths in amps per metre can be converted directly into flux density in microtesla by a simple factor. Hence, in air, magnetic flux density is directly proportional to magnetic field strength. As a result the use of microtesla to describe magnetic field strength has become widely used in this area of research.

**Table 5.5      Electric and Magnetic Field Strengths**

Voltage (kV)	Line Type	Electric Field (volts/m)				Magnetic Field (microtesla)			
		Distance from Centrelines(m)				Distance from Centrelines (m)			
		10	20	40	50	10	20	40	50
110	Single Circuit	850	250	40	-	2.7	1.0	0.3	-
110	Double Circuit	450	120	100	-	3.2	1.5	0.5	-
220	Single Circuit	2600	1200	200	-	4.2	2.0	0.6	-
220	Double Circuit	1900	400	250	-	3.8	2.2	0.8	-
400	Single Circuit	6000	3500	600	250	8.0	2.0	1.2	0.8
400	Double Circuit	6000	1400	500	400	7.0	4.5	1.8	1.2
500	Double Circuit	6000	1500	350	250	20.0	8.0	2.0	1.0
1100	Single Circuit	8500	8300	3300	1500	28.0	22.0	10.0	7.0

Sources: (ESB, 1988b; BPA, 1986).

Prior to the current public concern over possible hidden health effects, the standards employed in determining maximum field strengths under power transmission lines and the widths of rights-of-way were decided primarily on the basis of public safety. The need was to ensure that no one would be affected by electric shocks either directly or via currents induced in metal located within the right-of-way (e.g. from stepping down from a large truck parked under a transmission line where a line crossed a road). The rights-of-way required for power lines are based largely on these safety considerations. Estimates of the maximum strengths of electric and magnetic fields at the edges of the rights-of-way employed by the U.S. Department of Energy's Bonneville Power Administration are given in Table 5.6.

**Table 5.6**      **Maximum Electric and Magnetic Field Strengths at**  
**Edge of R.O.W.**

<b>Voltage</b>	<b>Line</b>	<b>Right-of-Way</b>	<b>Electric</b>	<b>Magnetic</b>
<b>(kV)</b>	<b>Type</b>	<b>Width</b>	<b>Field Strength</b>	<b>Field Strength</b>
		<b>(m)</b>	<b>(volts/m)</b>	<b>(microtesla)</b>
230	Double Circuit	30-38	300	2.5
500	Double Circuit	38-50	1500	8.0
1100	Single Circuit	64-70	4600	12.5

Source: (BPA, 1970)

The various national standards for electric and magnetic field exposures are set out in Tables 5.7 and 5.8 (Grandfolo and Vecchia, 1988). Where a range of standards is given the most stringent are quoted.

**Table 5.7      National Electric Field Exposure Standards**

County	<u>Exposure of General Public (volts per metre)</u>	
	Continuous Exposure	Intermittent Exposure
Australia (Victoria)	1000	2500
Czechoslovakia	-	10000
Fed. Rep. Germany	20000	30000
Japan	3000	7000
Poland	1000	10000
United Kingdom*	2600	12000
United States (Montana)	1000	7000
United States (New York)	1600	7000
U.S.S.R.	1000	10000
IRPA*	5000	10000

**Table 5.8      National Magnetic Field Exposure Standards**

County	<u>Exposure of General Public (microtesla)</u>	
	Continuous Exposure	Intermittent Exposure
Fed. Rep. Germany	5200	7800
United Kingdom*	180	780
U.S.S.R.	1820 (8hrs)	7800
IRPA*	200	not specified

\* In the United Kingdom and in the IRPA these recommendations are currently under review.



Few jurisdictions have promulgated electric and magnetic field strength standards on the basis of minimising possible athermal health effects. The International Radiation Protection Association has proposed (IRPA, 1987) that the general public should not be continuously exposed to electric fields exceeding 5000 volts/m or to magnetic fields in excess of 200 microtesla. On that basis one could deduce from Table 5.5. that one could safely dwell 10m distant from most powerlines. The UK National Radiological Protection Board proposed guidelines for long term exposure in residential areas of 2600 volts/m and 174 microtesla (NRPB, 1986). Even under these tighter guidelines one could still reside 10m away from 220kV lines without being exposed to excessive field strengths, if one accepted the NRPB guidelines.

Both NRPB and IRPA are currently in the process of revising their guidelines for electric and magnetic field exposure. It is expected that both organisations will publish new guidelines shortly. In the case of NRPB the new reference levels for continuous exposure of the public are expected to be (NRPB, 1988c):

electric field exposure :	12280 volts per metre
magnetic field exposure :	2000 microtesla

These more relaxed reference levels are aimed solely at preventing electric shocks and hazards of overheating in the body. As regards possible athermal effects, the advise to be given by NRPB is expected to say that there is insufficient data either to quantify a health risk or even to determine whether there is a potential hazard to health.

In contrast, IRPA are planning to tighten their exposure limits for the general public partly on the basis of problems faced by wearers of some types of heart pacemaker.

The actual numbers are likely to be as follows:

**Exposure of General Public to Electric and Magnetic Fields:**

(a) continuous, 24 hour exposure, including exposure in open spaces and recreational areas:

electric field limit : 5000 volts/metre

magnetic field limit : 50 microtesla

(b) short term and occasional exposure for a few hours per day:

electric field limit : 10,000 volts/metre

magnetic field limit : 500 microtesla

(c) except for exposures of less than a few minutes per day, the following limits should not be exceeded

electric field limit : 10,000 volts/metre

magnetic field limit : 500 microtesla

Two American states, Florida and New York, have now begun to formulate electromagnetic field standards for power lines, following extensive consideration of the public concerns over proposed and recently constructed high voltage power lines.

Florida has yet to specify field strength limits for existing power lines, but has drafted proposed standards for new lines (Florida, 1988). These standards are 1500 volts/metre maximum at the edge of the right-of-way, 8000 volts/metre maximum within the right-of-way

and 5 microtesla average magnetic field strength at the edge of the right-of-way. Also at no time may the instantaneous magnetic field exceed 10 microtesla. On this basis the width of right-of-way required for a 220kV line is of the order of 20 metres.

The state of New York is proposing to adopt, as an interim measure, a standard for 765kV lines that is based on the field strengths presently found at the edge of the rights-of-way of typical 345kV lines (New York State, 1988). The logic for this recommendation is that such fields (at the edges of 345kV lines) have been "a risk implicitly accepted by society over decades of operation of 345kV lines." The proposed New York rule means edge of right-of-way electric field strengths no greater than 1600 volts/metre and magnetic field strengths of about 5 microtesla. It is worth noting that the right-of-way specified for the 765kV lines is 350 ft (107m).

Essentially no new transmission line adopting the widths of rights-of-way normally employed in the construction of lines up to 500kV would have trouble meeting the New-York or Florida standards. However very high voltage lines such as the 1100kV prototype referred to in Table 5.6 would probably need wider rights-of-way than those now generally considered acceptable. While these standards would therefore present ESB with no major problem - if the standards were to be adopted in Ireland - they could create major difficulties worldwide if they were to be applied to homes and offices. Electric fields of 10000 volts/m have been measured in the vicinity of electric blankets (ITTRI, 1979). Magnetic fields of the order of 200 to 2000 microtesla have been measured adjacent to food mixers, electric drills, hairdryers

and electric cookers (Gauger, 1985). If, and it is a big 'if', the Florida magnetic field standard were to be universally adopted then logic would demand its extension to other major sources of magnetic field. The implications are daunting.

#### 5.5 Schools and Transmission Lines - Experience Elsewhere

There are a number of unresolved disputes involving schools and powerlines in Canada and the United States. There have also been cases of disputes which have been satisfactorily resolved.

Some of the unresolved disputes or disputes which were resolved only by exhausting all legal avenues include:

##### A) Houston, Texas

A school board was awarded \$25 million punitive damages in November 1985 against Houston Lighting and Power Co. because the utility had acted in "reckless disregard" to the health of schoolchildren by routing a 345kV line near to a 3-school complex. The utility was also required to relocate the line underground.

In November 1987 on appeal, the utility was found not liable to pay punitive damages but was obliged to reroute the line, which it later did at a cost of \$8 million (Health and Safety, 1987a). The school board concerned appealed to the Texas Supreme Court for reinstitution of the \$25 million penalty, but the appeal was rejected on July 6, 1988.

**B) Kanata, Ontario**

Residents objected to Ontario Hydro building a 500kV line on a right-of-way previously occupied by a 230kV line, because the line was near a 400 pupil elementary school. The 230 kV line had been constructed and was in use prior to the construction of the school. The school was built subsequently. The problem arose when Ontario Hydro decided to upgrade the line to 500 kV. Construction work was halted while the Ontario Government considered whether or not the residents claims of health hazard were legitimate. A report was commissioned from the Ontario Ministry of Health (see Section 4.3.5). After considering that report and a response to the report from the residents, the Ontario Cabinet in December 1987 gave the go ahead to Ontario Hydro to resume construction. The residents immediately applied to the Ontario Supreme Court for an injunction to stop the work pending a judicial review. This application was rejected by the Supreme Court.

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Following a parent-arranged boycott of the school, the local school board initiated a field measurement study to establish actual field strengths and sources. Six schools were measured, three close to and three away from power lines. Preliminary findings show no significant differences in field strengths in the schools measured.

The school board plans to conduct more measurements in October and November 1988, when the line is energized at 230 kV, and again in November 1989, when it will be upgraded to 500 kV.

C) Calgary, Alberta

A proposed 240kV line near a 200 pupil elementary school is being opposed by parents on health grounds. While the utility concerned has agreed to consider alternative routes it has not agreed to rule out the 'school' route. The problem is being considered by the Energy Resources Conservation Board of Alberta (Health and Safety, 1987b).

D) West Palm Beach, Florida

This is another case of construction of a school being delayed as a result of its being near a power line. A group of parents are protesting to the School Board over potential health effects (Health and Safety, 1988a).

Despite these foregoing instances of concern, there are other situations where the problems were amicably resolved, or at least made some progress:

E) Scottsdale, Arizona

This problem centred on a new school to be built 200 ft. from a utility substation. Concern arose following publication of the New York Power Lines report in July 1987. Thanks in part to the involvement of a trusted independent electrical engineering professor in measuring magnetic fields strengths the School Board were happy to proceed with construction (Health and Safety, 1987b).

However, every silver-lining is not without its cloud, and there is now concern being expressed among parents about the risk to their children of walking along a 69kV powerline right-of-way to the school (Health and Safety, 1988b).

**F) Apache Junction, Arizona**

Concern about locating new schools near to an existing 230kV transmission line led to the School Board sending a delegation to talk to EMF-health experts at a major conference on the subject held in November 1986. The delegation reported themselves satisfied that magnetic fields from appliances in the average household were stronger than any that could be expected from the power line. The School Board decided to proceed with the school building project.

However the alarm raised by the New York Power Lines report late in 1987 led to further local concern which has not been assuaged (Health and Safety, 1987b).

**G) Frankfort, New York**

In May 1986 the Frankfort-Schuyler School Board issued a statement that a New York Power Authority (NYPA) 345kV line did not pose a threat to children attending on elementary school near the right-of-way. However an agreement between the NYPA and the school to measure field strengths in the school after the line was energised and during the summer holidays when the children were out of school was upset when the power line was energised prior to the vacation. Despite separate measurements by engineers representing NYPA and the

parents giving the same results -- no change in EMF levels following the energisation -- the School Board is now pursuing a lawsuit against NYPA (Health and Safety, 1988d).

#### H) Waterloo, Ontario

Ontario Hydro, by carrying out magnetic field measurements in existing schools near to and far from overhead transmission lines, was able to demonstrate to the satisfaction of the Waterloo County School Board that the proposed site of a new school, adjacent to a double circuit 115kV was not exposed to excessive or unusual magnetic fields. This work was undertaken in 1987 and all results were published (Harvey, 1987).

In California, the major \$2 million investigation of EMF-health effects that got underway earlier this year, (California, 1988) has the official support of the California Parent-Teacher Association. It has as a specific objective the identification of any higher incidence of leukaemia or other cancers experienced by children who reside or attend school in close proximity to electrical utility facilities. The official policy of the California Department of Education calls for the following minimum distances between the edge of a school's property and the edge of a right-of-way for new schools (Health and Safety, 1988d):

100 feet for	100-110 kV lines
150 feet for	220-230 kV lines
250 feet for	345 kV lines



Concerning utility practices on permissible building and land use under powerlines, the general view in North America is that agriculture is encouraged, the use of power line rights-of-way in or near cities for recreation purposes is not discouraged, but that building is definitely not encouraged. In cities however there is often pressure to permit the use of such areas for car parking, warehousing, and the building of changing rooms for sports fields. In Ontario however no buildings are permitted under 500kV lines.

In Sweden day care centres have been traditionally built under power lines because the land was provided free of charge.

Professor Knave considered this practice should end, not because he had evidence of a problem but that "It was not wise to build it (a day care centre) under a power line". There was no proposal in Sweden to relocate existing centres.

#### 5.6 The Co. Wicklow Problem

A number of Co. Wicklow residents are opposing the commissioning of a 220kV double circuit transmission line from Carrickmines to Arklow. It is indeed this dispute that had led to the preparation of the present report. This project progressed through the normal planning channels. Permission for its construction was sought by ESB from Wicklow County Council and authorisation was obtained, subject to planning appeal. The decision of the County Council was appealed to An Bord Pleanála, the State Planning Appeals Board, by Bord Failte and by a residents group mainly on the grounds of adverse aesthetic impact on the environment. Although some health concerns were raised at the appeal, this was not the major issue at that time. An Bord Pleanála dismissed the appeal in January 1987 and construction of the line proceeded.

During 1987 the concerns among the residents over the possible adverse health effects of electromagnetic fields grew, particularly following the widespread publicity given to the Savitz epidemiological study for the New York State Power Lines Project following publication of the report in July of that year (Ahlbom et al, 1987).

The key concern now centred over two schools which are located close to the new 220kV line. It should be mentioned that the 220kV line replaces an existing 110kV line on the same route. Following representations from public representatives in the community and following due consideration of the matter, the Minister for Energy

suspended the commissioning of the line while he carried out a further appraisal of aspects of the problem. This report is part of that appraisal.

The situation concerning the Co. Wicklow schools and the transmission line is:

A) Kilmacanogue National School

The nearest part of the school building to the centre line of the transmission line right-of-way is 21 metres. From Table 5.5 it can be seen that the maximum likely electrical field strength at this distance will be less than 400 volts/m and the maximum likely magnetic field (due to the transmission line) will be under 2.2 microtesla. Such electromagnetic field strengths are significantly lower than the most stringent standards yet proposed (but as yet unapproved) for new power lines. These are the proposed Florida standards for new power lines:

maximum instantaneous magnetic field :	10 microtesla
maximum average magnetic field :	5 microtesla
maximum electric field strength :	1500 volts/m

.... where all measurements are taken at the edge of the right-of-way.

B) St. Catherine's National School

The situation at St. Catherine's National School is similar to Kilmacanogue, with the nearest school building also about 20 metres away. At St. Catherine's the pylons are some 12 metres higher than at Kilmacanogue. This would have the effect of further reducing both electric and magnetic field strengths to below the 400 volt/metre and 2.2 microtesla

maximum levels possible at Kilmacanogue. Field strengths should not approach even the extremely stringent levels being considered for lines as yet unbuilt in Florida.

Concerning playgrounds at the two schools, in both cases children have opportunity to play directly under the powerlines. They will therefore be exposed for short periods to the maximum potential electric and magnetic fields generated at ground level by the 220kV powerline. In worst case conditions these fields will be:

maximum electric field : 3300 volts per metre  
 maximum magnetic field : 4.2 microtesla

The projected maximum magnetic field strength is still well below the instantaneous maximum of 10 microtesla being considered by Florida (Florida, 1988). In the case of electric fields within the right-of-way the proposed Florida rule covering the maximum electric field strength permitted within the right of way recommends 8000 volts per metre. Limits on the maximum electric field strength to which the general public can be exposed for short periods have also been proposed by the State of New York (New York State, 1988), the International Radiological Protection Association (IRPA, 1987) and the U.K. National Radiological Protection Board (NRPB, 1986). These electric fields strength guidelines are:

State of New York	:	10,000 volts/m
IRPA	:	10,000 volts/m
NRPB	:	12,000 volts/m

While it is understood that both the IRPA and NRPB are likely to issue new guidelines shortly, in neither case do the new proposals for magnetic field exposure approach the stringency of the Florida proposals, nor are any significant changes planned by either body in their recommendations concerning public exposure to electric fields.

Hence on the basis of the latest assessment of risk, and in full knowledge of public concerns over electromagnetic fields, thresholds have been proposed by three different organisations which easily accommodate the maximum electric field strengths likely to occur over the school playgrounds.

In estimating the various electromagnetic field strengths in this section of the report, the writer was obliged to look at 'worst case' conditions. It is very likely that the exposures at the two schools will be less than those estimated.

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