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International Commission on Non-Ionizing
Radioprotection Protection

Madam, sir,

Hydro-Québec would like to thank ICNIRP for offering the opportunity to comment this important document. For more than 30 years, Hydro-Quebec has played an active role in better understanding the possible health effects of 60 Hz magnetic and electric fields. Through its strong commitment to offer its employees a safe and healthy working environment, Hydro-Québec responded early to the first concerns expressed in 1972 at a CIGRE session, suggesting that workers exposed to high electric fields were suffering of various non specific health problems by carrying out specific studies on this question. Later, in the '80, when a possible association between childhood cancer and extremely low magnetic fields was raised, HQ initiated a substantial research program including epidemiological studies and long-term experimental studies in collaboration with various health authorities and universities.

When ICNIRP guidelines were published in 1998, HQ gave its most serious considerations realizing the recognized expertise and the credibility of the organization and the lack of any specific provincial or federal guidelines for limiting exposure to 60 Hz electric and magnetic fields in Canada. An internal group of specialists were asked to analyse the guidelines and provide advice to the managers of the main divisions of the company including generation, transport and distribution.

The conclusion was reassuring but at the same time created some confusion. Indeed, at first sight, it was obvious that common exposure levels for our workers but also for the public exceeded the ICNIRP recommended "reference levels". However, the scientific evidence provided in the guidelines showed that the levels at which the public and the workers were exposed were not associated with any expected health effects. Indeed, our understanding was that some large safety factors had been applied by ICNIRP before recommending the reference levels.

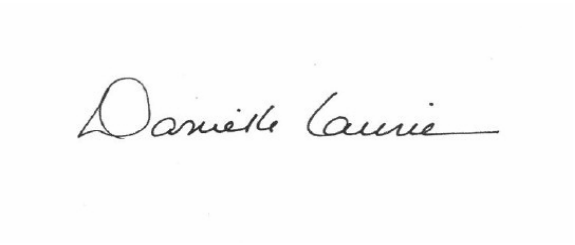
In 1998, HQ held a conference call with Health Canada, the Canadian Electricity Association and the former chairman of ICNIRP, Mr J. H. Bernhardt to discuss and better understand the guidelines. The same year, the Federal Provincial and Territorial Radiation Protection Committee (FPTRPC) working under the umbrella of Health Canada issued a statement including a brief review of the scientific evidence and ICNIRP guidelines. The FPTRPC concluded that current exposures to 60 Hz fields in Canada were safe and no specific legislation were needed.

In 2002, a second set of guidelines were published by another international organization, the IEEE International Committee on Electromagnetic Safety on Non-Ionizing Radiation. Although the scientific basis was essentially similar to ICNIRP, the recommended limits were considerably higher. The discrepancies between the two guidelines created much confusion which has persisted up to this day. In 2005, the FPTRPC underlined the confusion created by the two sets of international guidelines and hoped for some harmonization between the two.

In this context, the revision of ICNIRP guidelines offers an opportunity to clarify some technical and non-technical issues. Hydro-Québec standing committee on electromagnetic field effects prepared a set of comments that I am pleased to offer ICNIRP. As you will notice, we are particularly concerned by the lack of transparency and some inconsistencies in the method used by ICNIRP to derive the reference levels.

If you need any additional information or clarification, please let me know and I will make sure that our specialists be available to provide you with a quick response.

Sincerely,



Danielle Laurier

Comments of a Hydro-Québec Working Group on

THE DRAFT ICNIRP GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz TO 100 kHz)

of July 2009

October 20, 2009
Health and Safety Department

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Comments by a Hydro-Québec Working Group on the *DRAFT ICNIRP GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz TO 100 kHz) of July 2009*

1. General remarks

The fact that the ICNIRP is open to world-wide consultation on these draft guidelines is most welcome. However, the approach used to establish the reference levels is not completely transparent and requires clarification. The reasoning is hard to follow, mainly because choices made by the ICNIRP at different stages in the process are not clearly explained and referenced. In addition, the different parts of the document overlap and each includes arguments that are sometimes incomplete or scattered, making the document as a whole difficult to read. Last, the names and roles of the scientists who worked on the draft guidelines should be mentioned.

2. Rationale for the 2009 guidelines

Any normative document addressing health risks must clearly identify the harmful effects the document is meant to prevent. The different parts of the ICNIRP draft guidelines, however, speak of diverse biological effects resulting from exposure to electric fields without clearly stating which of these effects warrant the establishment of exposure limits. Is it the appearance of magnetophosphenes? disturbance of cognitive functions? spark discharges? or other effects? We are particularly perplexed by the following statement at line 281: "There is also strong indirect scientific evidence that CNS functions such as cognitive processing can be affected by induced electric fields below the threshold for direct stimulation." This is a serious claim, yet the ICNIRP does not explain the meaning of "can be affected," nor are any references given to support the statement. In addition, it is important to make a clear distinction between a stimulating effect and a harmful effect, as in lines 333 to 337, for example.

Also, in line 52, the ICNIRP does not quantify what is meant by a "high level of protection."

The ICNIRP also mentions that there is some degree of uncertainty in scientific knowledge in this field, which must be compensated for by "reduction factors" largely defined on the basis of "expert judgment" (lines 446 to 453). However, the assumptions used in determining and applying the reduction factors used to develop the guidelines are neither explained nor referenced.

Furthermore, there is considerable overlap in the definitions of "reduction factor" (line 1149) and "safety factor" (line 1175). We wonder if both terms are required.

3. Electric-field effects

In several places in the draft guidelines, the indirect effects of electric fields (spark discharges and contact currents) are discussed at the same time as the direct effects (induced electric fields) without any clear distinction between these three types of effects. We suggest that they be addressed separately.

3.1 Induced electric field

The direct effect of exposure to electric fields is addressed in the draft guidelines. For the basic restriction, the ICNIRP has selected 100 mV/m, that is, the lower estimate of possible effects on CNS

function. However, the draft guidelines do not explain how this basic restriction is converted to a reference level (kV/m). We feel it is important that the ICNIRP explain this conversion in the guidelines, indicating all references used.

3.2 Spark discharges

Spark discharges are momentary electrostatic phenomena that can cause a biological response depending on the total energy released by the arc, expressed in joules, or the total charge, expressed in coulombs. Studies demonstrate that the amount of energy released and the size of the charge are the best variables for determining effects induced in humans by spark discharges. In addition, spark discharges that occur on exposure to a strong electric field can cause discomfort and even some pain, as mentioned in the ICNIRP draft guidelines (lines 289 to 298). However, the guidelines fail to mention that spark discharges do not present any health risk: the threshold for muscle contraction is about 10 to 50 joules, whereas the energy released by spark discharges under a high-voltage line is never more than a few thousandths of a joule, that is, many thousand times less than this threshold. For purposes of comparison, the spark discharge of a defibrillator used to treat cardiac arrest is 100 to 300 joules.

We suggest, accordingly, that the ICNIRP guidelines clearly mention that the reference level for spark discharges is meant to prevent discomfort without health consequences, not to prevent a dangerous effect.

3.3 Contact current

A contact current is a sustained current that flows through the human body. Line 591 of the ICNIRP draft guidelines mentions that the recommended reference levels for contact currents are not intended to prevent perception of such currents but to avoid painful shocks. However, the reference levels recommended by the ICNIRP, 1 mA for occupational exposure and 0.5 mA for general public exposure, are not in line with generally recognized painful shock thresholds. The effects of contact currents are well-known and well-documented in the scientific literature. Perception threshold is about 1 mA and the maximum level considered to be without danger for human beings is about 5 mA. Let-go current ranges from 5 to 10 mA (about 9 mA for men and between 6 and 7 mA for women and children). This means that the ICNIRP reference levels of 1 mA for occupational exposure and 0.5 mA for general public exposure probably include a safety factor of 5 for workers and 10 for the general public. This is not mentioned in the ICNIRP draft guidelines.

In addition, the procedure used to convert the basic restrictions for indirect effects (expressed in joules or coulombs and mA) to reference levels (expressed in kV/m) should be explained in the guidelines. The worst-case exposure scenario used in the calculations should be part of this explanation as well.

4. Reference levels for power frequency fields (50 Hz and 60 Hz)

As power frequency electric and magnetic fields (50 Hz and 60 Hz) are a major issue, if not the major issue, in setting exposure limits, one would expect the ICNIRP to devote a table specifically to these frequencies. A table such as the following could be included:

	Basic restriction	Reference level
Induced electric field	mV/m (in the brain)	μT
Induced electric field	mV/m (in the brain)	kV/m
Spark discharges	joules or coulombs	kV/m
Contact current	milliamperes (hand-foot contact)	kV/m

5. Dosimetry

The ICNIRP describes as a significant advance the emergence of new heterogeneous conductivity models of the human body that allowed more anatomically and electrically realistic calculations and resulted in a much better knowledge of *in situ* electric fields in different body regions exposed to external fields (lines 418 to 421). A number of different researchers are mentioned, including Bahr and Dimbylow. However, in determining the relation between the basic restriction and reference levels, the ICNIRP draft guidelines use none of the heterogeneous models mentioned as so important, turning instead, it seems, to its own homogeneous and simple circular conductive loop model of 1998. This, at any rate, was what we concluded from note 4 at the bottom of Table 2 (line 438).

In addition, in line 533, the ICNIRP recommends determining the induced electric field as an average of the magnitude of the electric field in a cubical volume of 5x5x5 mm—which seems adequate to us if a model incorporating complex anatomical geometry and heterogeneous conductivity is used. However, we wonder why the guidelines make this recommendation when the ICNIRP itself has opted for a homogeneous and circular model (line 438).

Furthermore, at lines 545 and 546, the ICNIRP states that the reference levels were obtained by mathematical modelling and references ICNIRP 2003, Bahr et al 2005 and Dimbylow 2005-2006. The ICNIRP reference of 2003, however, contains no mathematical models: it is a general work on the effects of electric and magnetic fields. In addition, if the ICNIRP had used the Bahr and Dimbylow models, the reference levels would be much higher than those given in tables 3 and 4. Based on the information given in line 426, for example, a 50-Hz magnetic field (1 μT) induces an electric field in CNS tissue of 0.05-0.08 mV/m. By extrapolation, a basic restriction of 100 mV/m in CNS tissue would correspond to an external magnetic field of 1250-2000 μT—many times the reference level of 500 μT given by the ICNIRP for occupational exposure.

In other words, the model used by the ICNIRP is not explicitly described, nor are its parameters specified. Furthermore, as modeling of the human body is a fundamental step in calculating induced fields and determining reference levels, the ICNIRP guidelines should be very clear about the model used. In fact, a complete section of the guidelines should be devoted exclusively to describing and justifying the mathematical model used.

We want to point out as well that the conversion factor of 650 indicated in the last line of Table 2 is not explained either in the text or in the reference given (ICNIRP 1998). However, as this factor was "adopted for the relation between the basic restriction and reference level" (line 438), the ICNIRP should clearly explain how it was determined.

Last, in Figure 3, the gap between the reference level curves for occupational exposure and general public exposure to electric fields increases at frequencies higher than 100 Hz, but this is not explained in the text. This increased gap suggests that the safety factor for general public exposure increases with the frequency. If this is indeed the case, it should be explained in the guidelines.

6. Basic restriction

Line 484 states that the ICNIRP has selected a basic restriction of 100 mV/m in the central nervous system. In the 1998 version of the guidelines, however, the ICNIRP selected a basic restriction of 10 mA/m^2, specifying brain tissue conductivity of 0.2 S/m. We therefore deduce that the basic restriction of 1998, expressed as an induced electric field, was 50 mV/m (10 mA/m^2 ÷ 0.2 S/m = 50 mV/m). This means the basic restriction of 2009 is twice as permissive as the 1998 basic restriction. Logically then, the 2009 reference levels for magnetic fields should be twice those of 1998. For example, the occupational exposure reference level at 50 Hz should be 1000 µT instead of 500 µT. However, the 2009 ICNIRP draft guidelines still recommend a reference level of 500 µT, which is inconsistent with the calculations just explained.

Note that the nerve cell density in nerve tissue given in line 519 is incorrect, as it would result in a brain far too big for any human being. First, line 519 mentions 10^3 nerve cells per mm^2 instead of per mm^3. Correcting this first error and then using this density (10^3 nerve cells per mm^3) to calculate the size of the brain required to hold the roughly 100 billion (10^{11}) nerve cells in the adult brain, we get a brain of 10^8 mm^3, that is, 100 litres. The volume of the human brain, however, is about 1.5 litres.

Note as well that the numbering of the tables is incorrect: there are two tables called Table 2.

In the "second" Table 2, the 100 Hz – 1000 Hz frequency range is divided into two parts: 100 Hz – 200 Hz and 200 Hz – 1000 Hz. However, for the reference levels given in tables 3 and 4, this same frequency range is divided differently: 100 Hz - 400 Hz and 400 Hz – 1000 Hz. There is no explanation for this difference in the text. We don't know if this is a typing error or a scientifically based difference. If it is an error, which of the two divisions is correct?

7. Literature review

The 2009 draft guidelines begin with a reminder of the lack of scientific evidence of any causal relationship between exposure to extra low frequency EMFs and any disease. This is a positive point. In addition, the draft guidelines specifically mention that the existing scientific evidence that EMFs are causally associated with childhood leukemia is too weak to form the basis of exposure guidelines (lines 410 and 412). This too is positive.

However, in lines 253 to 257, the ICNIRP questions the validity of long-term animal studies in evaluating carcinogenesis in children. Long-term carcinogenicity studies in rodents to date have nonetheless demonstrated their predictive value: all products that proved carcinogenic in humans were also carcinogenic in animals, with predictive value especially high for physical agents. The protocols used to conduct these experiments, such as those of the NTP and the OECD, are rigorous and well-documented. These same protocols were used for studies of the effects of 50 and 60 Hz magnetic fields. In addition, the ICNIRP draft guidelines do not mention that these tests were conducted up to exposure levels of 5000 µT. Questioning the validity of these results means questioning the validity of the results obtained for all other products evaluated with these protocols.

Last, some of the most relevant studies of human volunteers are not mentioned, in particular the research conducted at the Lawson Health Research Institute in cooperation with the University of Western Ontario in London, Ontario, Canada, with a magnetic field of more than 1000 µT. (Legros, A., Beuter, A., *Bioelectromagnetics* 26, 657-669, 2005.)

8. Additivity of reference levels

In the 1998 guidelines, the ICNIRP states that "for the purpose of demonstrating compliance with the basic restrictions, the reference levels for the electric and magnetic fields should be considered separately and not additively." (Health Physics, Vol. 74, No. 4, April 1998, page 510). In 2009, however, the ICNIRP says exactly the opposite: "For the purpose of demonstrating compliance with the basic restrictions, the reference levels for electric and magnetic fields should be considered additively" (lines 568 and 569). No explanation for this change of approach is given in the 2009 draft guidelines.

Moreover, electric fields are vector quantities. To add them, one must know their spatial orientation and their phase lag. However, orientation and phase lag vary considerably from one point to the next within any one work space, (a substation, for example). Another difficulty arises from the fact that the presence of a human body distorts the electric field lines, further complicating the vector addition. Consequently, though it might be relevant, in theory, to add up induced electric fields for the purpose of demonstrating compliance with the basic restrictions, in practice, such addition is not feasible.

9. Protective measures

In lines 730 and 731, the ICNIRP implies that the World Health Organization (WHO) recommends the application of precautionary measures with respect to EMF exposure, referring the reader to two documents published in 2007, the book entitled *Environmental Health Criteria N^o 238: Extremely Low Frequency Fields* and *Fact sheet N^o 322: Electromagnetic fields and public health.* However, the title page of the book specifically warns that the report "does not necessarily represent the decisions or the stated policy of ... the World Health Organization." And in *Fact sheet N^{o}322,* published several months after the book, WHO gives its own point of view and makes no mention of or indirect allusion to precautions.

We would like to draw the attention of the ICNIRP to the negative impact that adopting precautionary measures might have on the public: anxiety, loss of property value, abandonment of community sites near high-voltage lines, etc. Consideration of this negative impact is especially important given that WHO states clearly in *Fact sheet N^o 322*, that "... policies based on the adoption of arbitrary low exposure limits are not warranted."

10. Conclusions

We believe that the ICNIRP should give a more transparent explanation of all steps in the scientific process used to develop the new 2009 guidelines. Specifically, we believe the ICNIRP should proceed as follows:

1- Identify the harmful effects that the guidelines are meant to prevent, giving the scientific references on which the conclusions of harmfulness are based.

2- Describe in detail the dosimetric calculations used to establish the reference levels corresponding to the basic restriction on electric fields induced in the CNS by external magnetic fields.

3- Explain the procedure used to establish the reference levels for exposure to electric fields (direct and indirect effects).

4- Present basic restrictions and recommended reference levels for each of the four following situations at power frequency (50 Hz and 60 Hz):

- Magnetic field exposure
- Electric field exposure (direct effect): induced electric field
- Electric field exposure (indirect effect): spark discharges
- Electric field exposure (indirect effect): contact currents

5- Leave it to government public health agencies to decide if any risk management actions are required (such as applying reduction factors and adopting precautionary measures) to address existing exposure levels in work and residential environments.

This report was prepared by a working group composed of the following:

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