Contact currents in Belgian residential housing

Prepared by Belgian BioElectroMagnetics Group (BBEMG)

Since 1979 and the first epidemiological study linking 60 Hz magnetic fields (MF) and childhood leukaemia, many studies have been conducted but have not reached a final conclusion yet. In 2002, with the epidemiological data in mind and without demonstration of any mechanism of action in laboratory studies (in animals exposed during their entire life or in cells), the International Agency for Research on Cancer classified 50 Hz MF field in the 2B class which means possibly carcinogenic to humans. In 2015, this association is still questioned.

For some years, researchers studied an attractive hypothesis based on contact currents. It was the aim of the project performed by the BBEMG engineers between 2005 and 2011. If such hypothesis could be verified, protective measures should be simple and based only on recommendations with respect to electrical installations.

What are contact currents?

Contact current is a current that runs through the body between two points of contact at different potentials (a device and the floor, a tap and the floor, a heater and the floor...) while this voltage is first of all not obvious since the connection to the voltage source is indirect (see examples in figure 1): contact current do not actually mean that there is a contact with active parts (contact with live parts, electrocution).

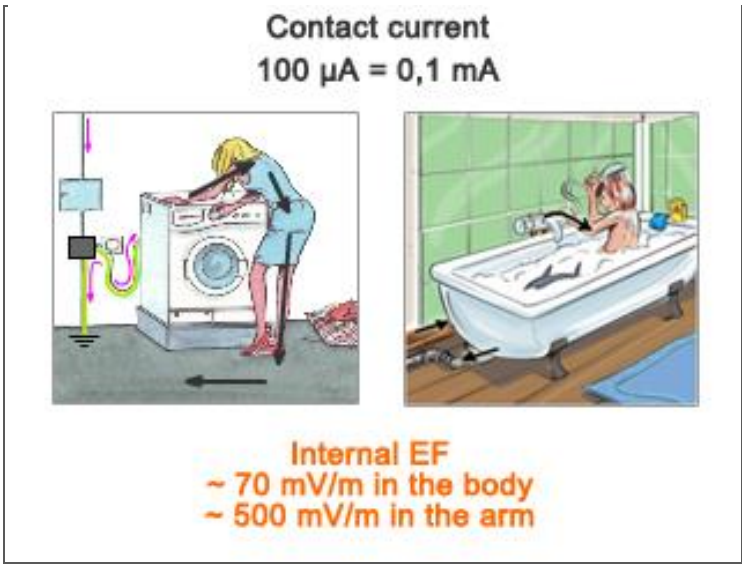

Figure 1 – Contact currents

Moreover, contact currents are neither induced currents, which are currents that can flow through the human body in relation to ambient electromagnetic fields, nor electrostatic discharges (ESD).

Contact currents are linked to a potential difference called “contact voltage”.

➔ *Let’s illustrate this by two examples:*

- In case of a partial degradation of the insulation of wires in an older washing machine (Figure 1, left) a leakage current can occur. It is a weak current not incompatible with an apparently normal functioning of the machine. Depending on the quality of the earthing of the frame of the washing machine, the frame could be raised to a potential different from the ground: between the person touching the frame and the ground a potential difference exists, meaning that a current will flow through the person.

  The current intensity flowing through the body will be low if the machine is correctly earthed and if the impedance of the person is high (namely dry hands and shoes that can partly insulate).

- The bathtub situation is a little bit trickier to understand!

  It depends on the equipotentiality of the conducting parts of the bathtub: metallic hoses and bathtub should be at the same potential to prevent electric shocks. It is done by connecting water pipes and/or bathtub to earth or by connecting each conducting parts with a protective wire (called equipotential bonding). Some parts could be even so at a different slightly potential for various reasons.

  For example, with regard to the bathtub, a potential difference could arise between the water inlet hose (the tap) and the drain hose. A child in his bath, playing with the tap could be crossed by a contact current. The child being naked and wet (low impedance), the current will flow through him/her even more easily than in the example above.

  Note: Hoses in PVC, less conductive, do not lead to contact voltage in the bathtub.

Contact current intensity can be weak. Very often, contact currents are not perceived (perception threshold of human being: around 0.5 mA).

For safety purposes related to electrocution risks, residential electric wirings are protected against fault currents when they exceed 300 mA, or even 30 mA (bathrooms), meaning that up to 30 mA the differential will not break the circuit (for example for a washing machine). Exceeding perception threshold will not directly trigger the circuit-breaker. Note that it would be mistaken to believe protecting our house wiring to levels lower than 30 mA because inopportune triggering would be too numerous.

Why studying contact currents?

Epidemiological studies and meta-analysis highlighted a small but increased risk of acute leukaemia for children exposed to average magnetic fields in excess of 0.3-0.4 µT. Years after years, researchers replicated studies, sought bias and confounding factors without reaching any final conclusion.

External magnetic fields could lead to effects on the human body through induced currents which give rise to low internal electric fields (rough estimate of 0.2 mV/m for a magnetic induction of 20 µT, see figure 2).

According to the World Health Organization (2007), 1 mV/m[1] (internal electric field) would be needed to potentially induce biological effects (not necessarily pathogenic). Therefore, external magnetic field could not alone explain the relation with childhood leukaemia.

[1] Based on current evidence threshold values around 10-100 mV/m seem more likely (WHO, 2007)

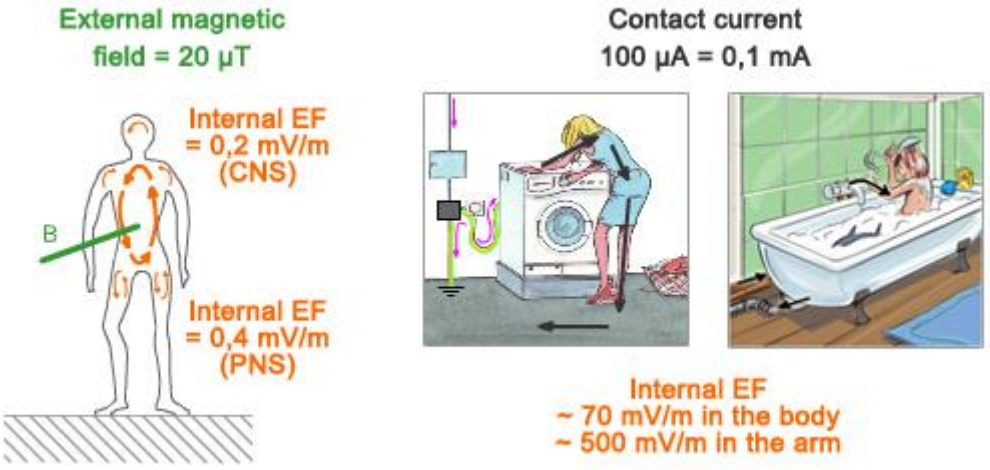

Figure 2

- ✓ **Should it be another factor related to magnetic fields that could explain the increased risk put in advance in epidemiological studies?**

The missing link could be contact currents. This hypothesis has been studied in the USA for 15 years.

- ✓ **Why focus on contact currents?**

It has been hypothesised that the relation showed in epidemiological studies without reaching any final conclusion could be due to an intermediate factor. Contact currents are plausible candidates to explain the link between childhood leukaemia and residential magnetic fields as highlighted by a study from the Electric Power Research Institute (EPRI): it reported a statistically significant relationship between contact voltages and the ambient magnetic field near power lines, meaning that higher contact voltages were measured in houses submitted to higher ambient magnetic fields.

These contact voltages may induce an electric field of a few mV/m in the child bone marrow[2] (for a realistic contact current value of a few microamperes) and without any sensitive reaction of the child.

Moreover, prior to launch the study on the relation between external magnetic fields and contact currents US researchers surveyed the frequency with which children are in contact with the tap when bathing (figure 2). Children's behaviours are consistent with frequent exposure.

This contact current's hypothesis was tested by BBEMG-members.

Contact currents in Belgian residential housing

The BBEMG research programme on contact currents was carried out in two phases. First, researchers performed a measurement campaign in Belgian residences to measure local ambient magnetic fields and evaluate contact current levels. Second, using the obtained results, possible correlation between the contact currents and the ambient magnetic field was analysed.

[2] It is hypothesized that acute lymphoid leukaemia could find its origin in bone marrow, the place where haematopoiesis (i.e. the formation of blood cellular components) is occurring during childhood.

- ✓ **In Belgium, is there a correlation between the proximity of overhead powerlines and contact current values in houses?**

Ambient magnetic fields and contact currents were measured during a five year period in about 150 houses in Belgium, 10 % of which had an ambient magnetic field higher than 0.4 µT (the houses were specifically chosen as close as possible to electrical power lines). The median value of the magnetic field measurements is 0.02 µT.

Contact currents were measured in the bathtub, in the shower and near electrical appliances such as the washing machine. The level of contact currents measured in the bathroom ranges from 1 to 1000 µA. The median contact current in the frequency graph is 8 µA. Twenty percents of houses have contact currents higher than 10µA and among them, 5% of have contact currents higher than 100 µA.

Contact currents were also measured near electrical appliances. In this case less than 50% of the houses present contact currents higher than 20 µA and among them 15% have contact currents greater than 100 µA.

No correlation was found between ambient magnetic fields in residence and contact current values (figure 3). In some houses, even with very weak ambient magnetic field (0.01 µT), significant contact currents are measured.

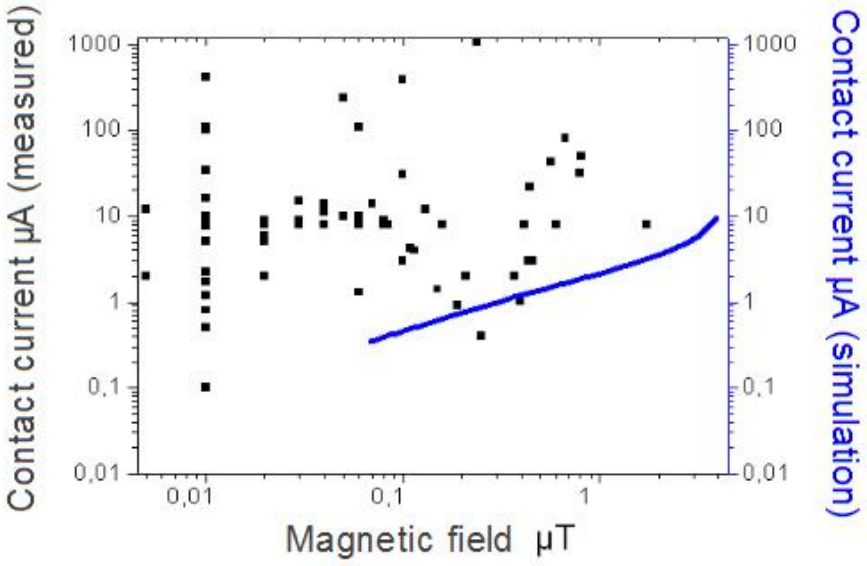

Figure 3 - Contact current versus ambient magnetic field. The dots indicate measured values in the sample of Belgian houses. The solid line represents the simulated value of contact currents (US hypothesis) due only to the ambient magnetic field (US hypothesis).

The solid line in Figure 3 can be considered as the part of contact currents that could be induced by the external magnetic field only. The ambient magnetic field alone can thus not justify the measured values of contact currents in the sample of Belgian houses.

These results are not in accordance with the US study. After analysing many parameters Belgian researchers hypothesised that the most probable cause of contact currents in Belgian residences could be leakage capacitive current.

- ✓ **Could leakage capacitive current be a satisfactory explanation of contact currents in Belgian residences?**

We already introduced leakage currents with the example of the washing machine above. These are **leakage resistive currents**.

Leakage capacitive currents exist continuously as it is due to the fact that some of the alternating current escapes the wires, even in perfect condition, by capacitive effect between any cable and a reference potential area. As most of the residential electrical cables have no metallic screens, capacitive currents may reach the earth wire, as well as any metallic ducts like the ones carrying water and gas.

For studying capacitive currents, it is important to understand that the masonry in which a cable is sealed can be considered as a good conductor, able to carrying currents towards other cables or tubing. Hence, the most important values to consider is between a conductor and the surrounding masonry.

Leakage capacitive currents of typical electrical cables used in Belgian houses at 230 V (between phase and neutral wires) are comprised between 3 and 13 µA/m. Since houses usually contain hundreds of meters of such electrical cable, these leakage currents could indeed give rise to significant voltage differences between metallic ducts in their vicinity.

Researchers performed various measurements to test the hypothesis. They concluded that, **in Belgium, contact currents are due to a capacitive effect rather than to the presence of an ambient magnetic field**.

- ✓ **How to understand differences between the origin of contact currents in Belgian and in the US residential housing?**

Two technical factors can explain this difference: on one hand, the characteristics of leakage capacitive currents, on the other hand the influence of the grounding system.

On one hand, the main voltage in residential housing in the USA is 110 V (at 60 Hz), while it is 230 V (at 50 Hz) in Belgium. Since capacitive leakage currents increase with increasing voltage, higher capacitive leakage currents are expected in Belgium, leading to potentially higher contact currents.

On the other hand, the grounding system in US is more prone to the apparition of contact voltages induced in pipes and wires by the 60 Hz magnetic fields from the electrical network.

Conclusion

The contact current hypothesis as the missing link was interesting in the USA. However, in Belgium, it does not allow us to connect external magnetic fields and childhood leukaemia.

Note that in 2011 US researchers published the results of an epidemiological study investigating the association between contact voltage exposure and childhood leukaemia in California. The authors concluded that in this population, there was no evidence of an association between childhood leukaemia and exposure to contact voltage or magnetic fields and a weak correlation between measurements of contact current and magnetic fields. Contact currents should not be the missing link in the USA either!

That does not prevent us from taking contact currents into account. As currents that cross our body correspond to quite high internal electric fields, it makes sense to check our electrical installation. BBEMG engineers noticed that a lot of private electrical wirings do not meet legislation standards and could correspond to high contact currents. It is recommended to **check the conformity of the house wiring**, with particular attention being paid to the quality of the earth and the presence of equipotential bonding between metallic pipes (water and gas), radiators and the grounding, and the distance between wires and pipes.

Contact currents depending on the body impedance, for the same potential difference, they would be larger through a naked wet person than through a dry person wearing shoes. Thus it is of importance to particularly insist on the rooms with water (bathroom as a priority) with the installation of appropriate differentials.

It should be noted that in well-designed house wiring in good maintenance, contact current intensities are generally very weak. Moreover, given the modernisation of the residential equipment, in particular the use of PVC water pipes, contact voltage is expected to drop. Eventually, as the name suggests,

contact currents could occur in case of a contact with a conductive frame of an electrical equipment meaning that people are not continuously submitted to these currents.

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