Eskom

Mr C Janse van Rensberg
Midstream Electrical Services
Midstream Estate
Brakfontein Road

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Enquiries: Roy Hubbard
Tel +27 11 629 5236
Cell +27 82 415 0688
roy.hubbard@eskom.co.za

Dear Mr Janse van Rensberg

ELECTRIC AND MAGNETIC FIELD (EMF) EXPOSURE TO HUMANS AND INTERFERENCE FROM POWER LINES

In response to your request, Eskom Research, Test and Development (RT&D) forwards you the following in answering your health and interference concerns with respect to power lines. We thank you for bringing this issue to our attention.

Public safety is a critical priority for Eskom and we are therefore continuously engaged in extensive research and tests to ensure that electromagnetic frequencies from high-voltage power lines meet internationally accepted legislative requirements in respect of health, safety and interference. Your complaint provided us with an opportunity to further explore the effects of EMFs and interference related to power lines.

International standards prescribe the acceptable degree to which people may be exposed to electric and magnetic fields. The South African Department of Health has endorsed the International Commission on Non-ionizing Radiation Protection (ICNIRP) guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). These guidelines call for exposure limits, for the general public, of 5 000 V/m (volts per metre) (5 kV/m) and 200 μT (micro Tesla) respectively for electric and magnetic fields at 50 Hz. Eskom has used an electric field design limit of 10 kV/m in the past and thus sets the exposure limit within the servitude area, while meeting the 5 kV/m at the servitude boundary.

Having visited the site, in the Midstream Estate, beneath the four 400 kV and one 275 kV transmission lines, in response to your request for EMF exposure assessment, the following can be noted.

EMF measurements were conducted on the 24th July 2012 between 12:00 and 13:30.

A NARDA ELF exposure system (Serial No: K-0044) was used to measure the electric and magnetic fields.

Measurements were conducted at 2 m intervals starting at the side closest to the school and shopping centre along the pathway next to the road. This is presented in Map 1.

MAP 1: Layout of Midstream Estate, where the Measurements were Conducted

Further to the measurements conducted, predictions were also performed to see what would happen if the load varies. To verify the model with the measurements, the maximum recorded and predicted electric and magnetic fields were found beneath the transmission line inside the servitude boundary. Table 1 shows the maximum recorded and predicted electric and magnetic fields for the on-site measurements for comparison.

TABLE 1: Maximum Electric and Magnetic Fields

	MEASURED	**PREDICTED**
ELECTRIC FIELD (kV/m)	6.794	7.842
MAGNETIC FIELD (μT)	25.44	27.96

The measured electric and magnetic fields are shown graphically in Figure 1.

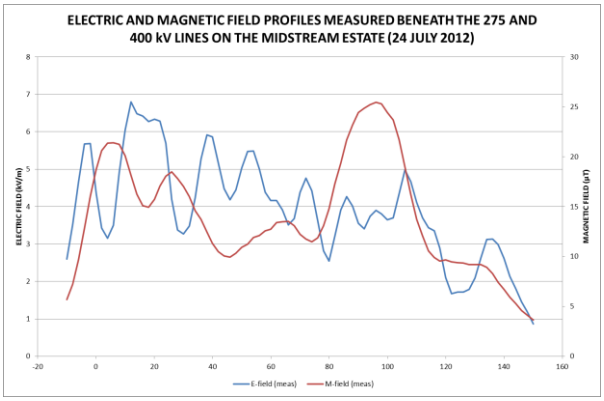

FIGURE 1: Electric and Magnetic Fields Beneath the Transmission Lines in Midstream Estate

The loads on the transmission lines at the time of measurement, is shown in Figure 2. It can be noted, that the loads did not vary substantially during the measurement times.

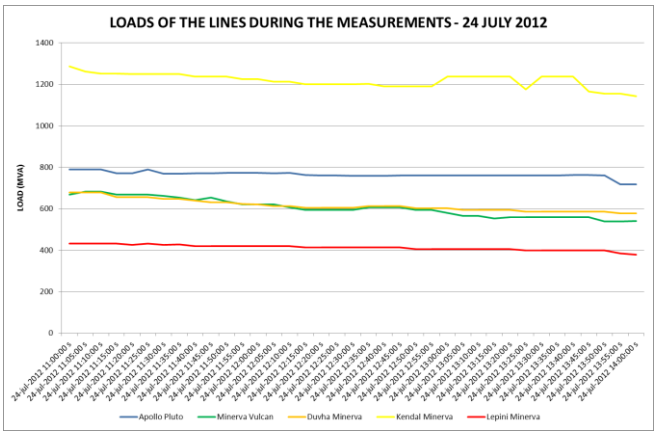

FIGURE 2: Transmission Line Loads During Measurements

The predicted electric and magnetic fields are shown in Figure 3.

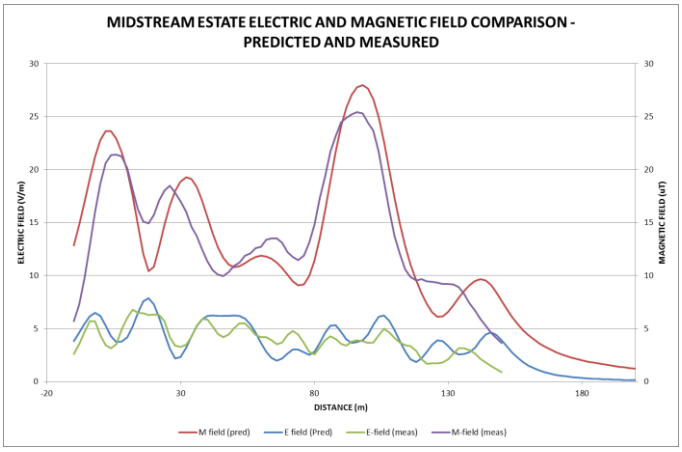

FIGURE 3: Predicted Electric and Magnetic Fields

EMF BACKGROUND

Everyone is exposed to a complex mix of EMF of different frequencies that permeate our environment. Exposures too many EMF frequencies are increasing significantly as technology advances unabated and new applications are found.

While the enormous benefits of using electricity in everyday life and health care are unquestioned, during the past 20 years the general public has become increasingly concerned about potential adverse health effects of exposure to electric and magnetic fields (EMF) at extremely low frequencies (ELF). Such exposures arise mainly from the transmission and use of electrical energy at the power frequencies of 50/60 Hz.

The World Health Organization (WHO) is addressing the associated health issues through the International Electromagnetic Fields Project. Any health consequence needs to be clearly identified and appropriate mitigation steps taken if deemed necessary. Present research results are often contradictory. This adds to public concern, confusion and lack of confidence that supportable conclusions about safety can be reached.

HEALTH EFFECTS OF EMF

The only practical way that Extremely Low Frequency (ELF) fields interact with living tissues is by inducing electric fields and currents in them. However, the magnitude of these induced currents from exposure to ELF fields at levels normally found in our environment is less than the currents occurring naturally in the body.

Electric Field Studies: Available evidence suggests that, apart from stimulation arising from electric charge induced on the surface of the body, the effects of exposures of up to 20 kV/m (kilo volts per meter) are few and innocuous. Electric fields have not been shown to have any effect on reproduction or development in animals at strengths over 100 kV/m.

Magnetic Field Studies: There is little confirmed experimental evidence that ELF magnetic fields can affect human physiology and behaviour at field strengths found in the home or environment. Exposure of volunteers for several hours to ELF fields up to 5 mT (milli-Tesla) had little effect on a number of clinical and physiological tests, including blood changes, ECG, heart rate, blood pressure, and body temperature.

Melatonin: Some investigators have reported that ELF field exposure may suppress secretion of melatonin, a hormone connected with our day-night rhythms. It has been suggested that melatonin might be protective against breast cancer so that such suppression might contribute to an increased incidence of breast cancer already initiated by other agents. While there is some evidence for melatonin effects in laboratory animals, volunteer studies have not confirmed such changes in humans.

Cancer: There is no convincing evidence that exposure to ELF fields cause direct damage to biological molecules, including DNA. It is thus unlikely that they could initiate the process of carcinogenesis. However, studies are still underway to determine if ELF exposure can influence cancer promotion or co-promotion. Recent animal studies have not found evidence that ELF field exposure affects cancer incidence.

Epidemiological Studies: In 1979 Wertheimer and Leeper reported an association between childhood leukaemia and certain features of the wiring connecting their homes to the electrical distribution lines. Since then, a large number of studies have been conducted to follow up this important result. Analysis of these papers by the US National Academy of Sciences in 1996 suggested that residence near power lines was associated with an elevated risk of childhood leukaemia (relative risk RR=1.5), but not with other cancers. A similar association between cancer and residential exposure of adults was not seen from these studies.

Many studies published during the last decade on occupational exposure to ELF fields have exhibited a number of inconsistencies. They suggest there may be a small elevation in the risk of leukaemia among electrical workers. However, confounding factors, such as possible exposures to chemicals in the work environment, have not been adequately taken into account in many of them. Assessment of ELF field exposure has not correlated well with the cancer risk among exposed subjects. Therefore, a cause-and-effect link between ELF field exposure and cancer has not been confirmed.

NIEHS Panel: The US National Institute of Environmental Health Sciences (NIEHS) has completed its 5-year RAPID Program. The RAPID Program replicated and extended studies reporting effects with possible health implications, and conducted further studies to determine if indeed there was any health consequence from ELF field exposure. In June 1998, NIEHS convened an international Working Group to review the research results. NIEHS's international panel concluded, using criteria established by the International Agency for Research on Cancer (IARC), that ELF fields should be considered as a "possible human carcinogen".

"Possible human carcinogen" is the weakest of three categories ("possibly carcinogenic to humans", "probably carcinogenic to humans" and "is carcinogenic to humans") used by IARC to classify scientific evidence on potential carcinogens. IARC has two further classifications of scientific evidence: "is not classifiable" and "is probably not carcinogenic to humans", but the NIEHS Working Group considered there was enough evidence to eliminate these categories.

"Possible human carcinogen" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. Thus **the classification is based on the strength of scientific evidence, not on the strength of carcinogenicity or risk of cancer from the agent.** Thus, "possible human carcinogen" means limited credible evidence exists suggesting that exposure to ELF fields may cause cancer. While it cannot be excluded that ELF field exposure causes cancer from available evidence, further focused, high quality research is now needed to resolve this issue.

The decision of the NIEHS Working Group was based mainly on the appearance of consistency in epidemiological studies suggesting residence near power lines resulted in an apparently higher risk of leukaemia in children. Support for this association was found in studies relating childhood leukaemia incidence to proximity to power lines and to magnetic fields measured for 24 hours in homes. Furthermore, the Working Group also found limited evidence for an increased occurrence of chronic lymphocytic leukaemia in the occupational setting.

ELECTROSTATIC INDUCTION

Electrostatic induction occurs when alternating 50-Hz electric fields couple with conductive animate (humans) and inanimate objects, thereby inducing currents and voltages within the objects. The actual current consists of minute movements of charged particles: electrons in metallic conductors and ionic conduction in body tissues and fluids. The voltages and currents induced directly into humans are of concern if they are high enough to cause direct biological, physiological, and psychological effects.

If the conductive object is grounded, the induced current that travels through the object to the ground is called the *short-circuit* current (units in amperes). Generally, in humans and animals the *short-circuit* current flows from head to feet (called body currents) and can be approximated with the following formula:

$$I_{\text{short-circuit (microamps)}} = 5.4(h^2_{\text{height (meters)}})(E_{\text{kV/m}})$$

Examples of measured *short-circuit* currents in 2 kV/m and 7 kV/m electric fields similar to those under 275 kV and 400 kV overhead transmission line are presented in Table 2 in micro-amps (µA).

TABLE 2: Short Circuit Currents in Various Objects

OBJECTS	275 kV LINE 2 kV/m E-FIELD (µA)	400 kV LINE 7 kV/m E-FIELD (µA)
Human – 1,75 m tall	32	112
Station wagon	220	770
Large bus	820	2870
Large trailer truck	1260	4410

Within elevated *electric fields,* when a grounded person touches an isolated (ungrounded) conductive object, a perceptible current (tingling sensation) or shock may occur. This phenomena also happens when the person is insulated and the conductive object is grounded. There are three basic classifications for shocks:

- Perception;
- secondary shocks (which are annoying but not harmful); and
- primary shocks (which are very dangerous and potentially lethal).

A safe perception shock (tingling response) for most men and women is 1.0 mA and 0.65 mA, respectively.

Secondary shocks invoke involuntary muscle responses (shaking) that are very annoying and possibly painful. However, primary shocks begin at the *let-go current* where 99.5 % of all subjects can still voluntarily *let-go* of an energized conductor: 9.0 mA for men and 6.0 mA for women. Unfortunately, beyond the *let-go current* threshold, a victim's heart may be shocked into ventricular fibrillation resulting in imminent death if not medically treated (defibrillated) within 4-6 minutes. Near transmission lines, the National Electrical Safety Code (N.E.S.C.) specifies 5 mA as the maximum allowable *short-circuit current* from vehicles, trucks, and equipment. In South Africa, this practice is also followed in terms of safety.

ELECTROMAGNETIC INDUCTION

Electromagnetic induction occurs when alternating 50-Hz magnetic fields couple with animate (humans) and inanimate conductive objects (wires, metal beams, HVAC ducts, etc.), thereby inducing circulating currents and voltages. Magnetically induced body currents in human tissues flow primarily in peripheral loops (called eddy currents) perpendicular to the field; however, current at the centre is generally near zero. Magnetic fields from transmission lines will normally induce voltages at the open ends of long, partially grounded, parallel conductors (fences, wires, and exposed pipes). So, dangerous and potentially lethal shocks from *electromagnetic induction* are also a serious problem.

Unfortunately*, electromagnetic induction* generates circulating tissue currents in humans near **transformers, network protectors, secondary feeders, switchgears, distribution busways, and electrical panels.** In calculating the *current density* in human tissues due to *electromagnetic induction,* the conductivity of mammalian tissue is assumed to be uniform: $\sigma_{conductivity}$ **= 0.1 S/m** (siemens/meter). Assuming the human body is within a conducting sphere, the *induced voltage* $\mathbf{E_i}$ in volts/meter (V/m) at a defined radius $\mathbf{r_{meters}}$ representing a waist of 0.145 m is defined as:

$$\mathbf{E_i = (1 \times 10^{-6})(\pi)(r_{meters})(f_{frequency})(B_{\mu T}).}$$

The *current density* $\mathbf{J_{body}}$ in micro-amps/meter^2 ($\mu A/m^2$) for human body tissues around the waist can be calculated by using:

$$\mathbf{J_{body} = (\sigma_{conductivity})(E_i)}.$$

Table 3 is a list of 50-Hz calculated *electromagnetically induced voltages* $\mathbf{E_i}$ and *current densities* $\mathbf{J_{body}}$ around a typical waist exposed to various magnetic flux density $\mathbf{B_{\mu T}}$ levels (also equivalent *short-circuit* currents induced within humans from *Efield electrostatic induction* in italics):

TABLE 3: Induced Electric Field and Current Density in the Body

MAGNETIC FLUX (μT)	INDUCED VOLTAGE - E_i (mV/m)	INDUCED CURRENT DENSITY ($\mu A/m^2$)
500	11.388	1138.8
100	2.278	227.8
50	1.139	113.9
10	0.228	22.8
5	0.114	11.4
1	0.023	2.3
0.3	0.007	0.7

CONCLUDING REMARKS

The error between the measured and predicted values for the electric and magnetic field are 15.4% and 9.9% respectively. This gives confidence that the predicted values are in good correlation with the measured values. Weather parameters as well as varied heights of conductors play a part in the measurements and predictions.

From the measurements and predictions conducted, it is evident that:

- Both the electric and magnetic fields measured and predicted are below the electric and magnetic field reference levels for the general public exposure of 10 kV/m and 200 μT respectively.
- The maximum electric field will produce a maximum short circuit current of 112.36 μA and 129.69 μA respectively.
- The maximum magnetic field measured and predicted, will produce an induced voltage and an induced current density as shown in Table 4.

TABLE 4: Induced Voltage and Current Density of the Human Body at Measured Load

INDUCED VOLTAGE - E_i (mV/m)		**INDUCED CURRENT DENSITY ($\mu A/m^2$)**	
MEASURED	**PREDICTED**	**MEASURED**	**PREDICTED**
0.579	0.637	57.94	63.68

From the values calculated (electrostatic and electromagnetic induction), the risk of shock can be classified as a perception shock and is not of a value, that could cause concern. This is similar to an electrostatic discharge felt in dry conditions when walking across a carpet and touching a door handle.

We would nevertheless like to thank you for bringing this matter to our attention.

Eskom understands and takes cognisance of your concern about these health issues and interference problems related to power lines, as communicated to us.

Electric and magnetic field exposure from the overhead power lines, will meet the ICNIRP international guideline as endorsed by the Department of Health of South Africa at the servitude boundary.

If we can be of any further assistance, please do not hesitate to contact our offices.

Yours sincerely

(Sent electronically, thus not signed)

KR Hubbard
SENIOR CONSULTANT (EMF/EMC)