INVESTIGATIONS OF EXPOSITION TO LOW FREQUENCY MAGNETIC FIELDS

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Abstract

1976 in the USA, Wertheimer-Leeper reported on an increased frequency of leukemia desease of children living near over-head lines. Since then, many epidemiological studies have been made on the subject of cancer and exposition to low magnetic flux densities of low frequencies. However, the results were contradictional. The above studies mentioned risk values from about 100 nT up to 400 nT over long durations. The presented paper reports on measurements in flats, mainly situated in Berlin, as well as at different working places in industry. The intensity and temporal influence of exposition in both these cases are not comparable. The problems of different measuring methodologies are emphasized.

1 Introduction

With the introduction of electric energy in all branches of economy, especially in industry, research, medicine and in households. Human beings have been exposed to electromagnetic fields. The intensity of which sometimes lies several orders of magnitude above that of natural fields.

For some time now, reports in the media can be found more and more on the alleged detrimental health effects of electric and magnetic fields.

Over-head lines for the transmission of electrical energy are especially suspected as well as electrical apparatus in general as being the cause of cancer generative magnetic fields /1/. In the epidemiological study from Wertheimer-Leeper, it was shown that children living in the vicinity of over-head lines contracted tumors and leukemia twice as often as those children who were not subjected to these environmental conditions. These investigations were received with divided opinions within the circles of experts. The critics made reference especially to the manner in which the presentation of evidence was made, such as the introduction of the so-called "Wertheimer-Leeper-Code", or wire code, according to which the magnetic fields were not measured, but only estimated from the cross-section of the conductors, the number of conductors and the distance from location /2/,/3/.

Savitz /4/ also indicated allusions in his study to the increased number of leukemia cases of children, who lived in the proximity of over-head lines. He repeated the study made by Wertheimer-Leeper and achieved similar results.

Furthermore magnetic fields are suspected to be also noxious to adult people. In this case the higher fields found on working places are assumed to be responsible for some health trouble. Hence, the research is at the beginning. No systematic measuring method exists up to now.

Although many of the magnetic phenomena seen by Wertheimer-Leeper in their study can be explained by the wire lay-out, the wire code allows field assessment only with limited accuracy. Harmonics, current load and its temporal fluctuation and partly highly significantly enhanced magnetic fields due to stray return currents can not be seen from an inspection of the cable lay-out.

Full details of the actual exposition values caused by magnetic flux densities can only be obtained from measurements /5/. In order to determine the flux density values occurring in electrical transmission and distribution networks up to the consumer in the factory or in households, large scale measurements under various conditions have to be carried out.

2 Epidemiological Studies

For many years world-wide epidemiological studies have been carried out with the object of proving a possible correlation between weak magnetic fields and cases of leukemia or tumors in children /6/. The exposition values, at which an increased sickness risk has being observed differ from study to study.

In the Danish study by Ohlsen /6/, published in 1993, a significant relation between all types of childhood cancer was stated for mean field strength values higher than 400 nT. Other authors /6/ consider a critical value of 100 nT. All these studies have something in common: they were retrospective.

The values are by far lower than the limits stated by IRPA (International Radiation Protection Association, working in close co-operation with the WHO):

- 100μT acceptable in cases of continuous exposition
- 1000μT acceptable in cases of short time exposition for a few hours per day.

But IPRA did not base their limits on possible long term effects.

3 Measuring Methods

The magnetic field in the human environment varies extremely depending on time and space.

Every method of recording the magnetic field in investigations to prove any health effects is not unambiguous right or wrong, due to the lack of knowledge about the effects caused by magnetic fields in the human body. The investigations deal with the so called "window effects" /8/ or refer to combined effects with the earth's magnetic field show the difficulties in measuring the fields. At the moment there is no quantity (amplitude, mean, harmonics, polarisation and so on) which correlates clearly with e.g. the appearing of cancer.

In the event of long-term effects being presumed, the total field dosage (exposure time integral) as an exposition criterion should be assumed. This assumption has been used as a basis in the previous epidemiological studies. It has been reported that various exposition criteria (e.g. mean value, geometric mean value, median) correlate with each other /2/,/9/,/10/.

For the purpose of monitoring the numerous measurements at various locations and at different times, the EMDEX exposure system, developed in the USA by ENERTECH, supported by the EPRI (Electric Power Research Institute) was employed /7/. With this instrument, only a time dependent measurement is possible. To record fields along a measurement path, the device is mounted on a wheel. The covered distance is recorded by the EMDEX system. The values are sampled every 30 cm. The EMDEX-measuring system records magnetic fields in a frequency range from 40 Hz up to 800 Hz.

4 Measurements Carried Out

Measurements were made in houses and at working places in industry. The results show, that the exposition values which occur in households basically differ from those occurring in industry with respect to course and amplitude. The essential differences are described in the following passages.

4.1 Measurements in private dwellings

To get the neccessary information of the field intensity two different kinds of measurements have been carried out according to Stamm /10/:

- **Spatial distribution**
  A typical measurement path is shown in Figure 1.
- **Temporal distribution** In every measured flat two field sensors were placed for 24 h in the center of a room frequently used by the child (e.g. living room) and near the pillow of the child's bed. A typical position of the places for the EMDEX-System is shown in Figure 1. The EMDEX-System was adjusted to take every 10 seconds a field-value.

The magnetic field in detached houses are uninfluenced by other tenants or neighbours. For this reason this type of measurements were used as a comparison to data gained in

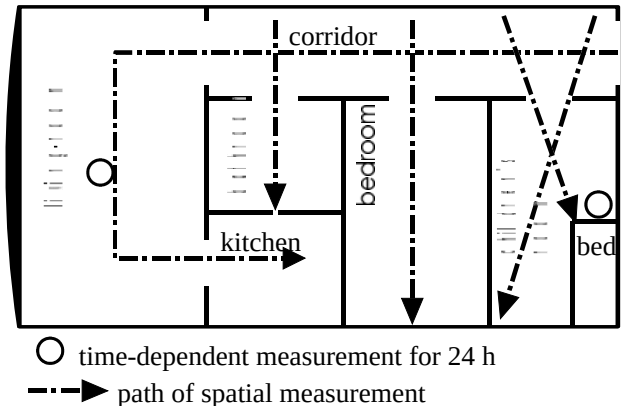

Figure 1: *Example for taking field measurements in a flat*

large blocks of flats in districts with high population density. In a total number of 26 detached houses the temporal and spatial distribution were measured. A typical cable lay out and the associated measurement result are shown in figures 2 and 3.

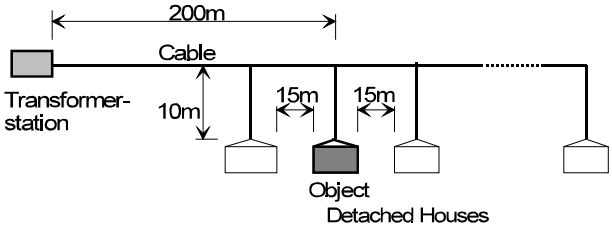

Figure 2: *Cable lay-out in the vicinity of a typical detached house*

As the transformer station was 200 m away its influence was negligible. The individual houses were supplied from a radial circuit. The distance to the neighbouring houses is 15 m.

The result of a 24 hour-measurement in this detached house is shown in Figure 3.

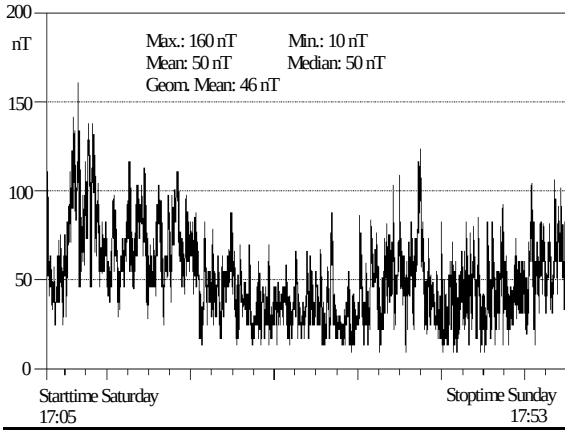

Figure 3: *Magnetic flux density in a detached house over a 24 h period.*

The curve shows distinct day and night phases in the flux density trace. The maximum, minimum, median, average values considered as criteria for exposition are low when judged as absolute values. Furthermore, they are also low when related to the value of 100 nT, which has been observed by several epidemiological studies as an approximate threshold for the occurrence of leukaemia with children /6/.

Two construction types of multi family housings are typically for Berlin and of course the detached houses in the suburban parts:

i) 5-6 storey houses constructed before World War II. (referenced as 'old houses')

ii) High rise blocks of flats of 6-25 stores constructed in the seventies and eighties mainly in suburban areas of high population density (referenced as 'high rise')

iii) Detached houses as mentioned above

Of the numerous measurements taken up to now, 76 flats could be clearly assigned to this classification. The gained values are tabulated below:

Magnetic field values [nT]		high rise N = 27	detached houses N = 26	old houses N = 23
spatial distribution	mean[1]	96.7	53.7	136.3
	std[2]	109.5	41.3	183.4
temporal distribution	mean[3]	41.8	46.4	80.6
	std[2]	70.8	58.8	81.8

Table 1: *Magnetic field exposition in different types of houses.*

The field values in detached houses are the lowest of all groups. From these measurements follows the dependency of the fields on the population density. The population density rises in the following direction: single houses, high rise blocks and old houses.

The extrem high standard-deviation of the measurements in old houses is caused by the two different kinds of electrical installation in the older flats, some are renewed others not. Older installations produce, due to the insufficient division of neutral and gas- or water-pipes high stray currents. Increased magnetic fields were found in the vicinity of gas and water pipes.

The results of some of these measurements made in residences of large blocks of flats are shown in Figure **Fehler! Textmarke nicht definiert.**.

For each of the 10 residences, symbols in the legend from top to bottom indicate: maximum, 95%-, 75%-, 50%-, 25%- and 5%-percentile, minimum, algebraic mean value.

Typical for these measurements is the weak distinctive transition between the day and night phases with a short minimum during the night. The values are appreciably higher

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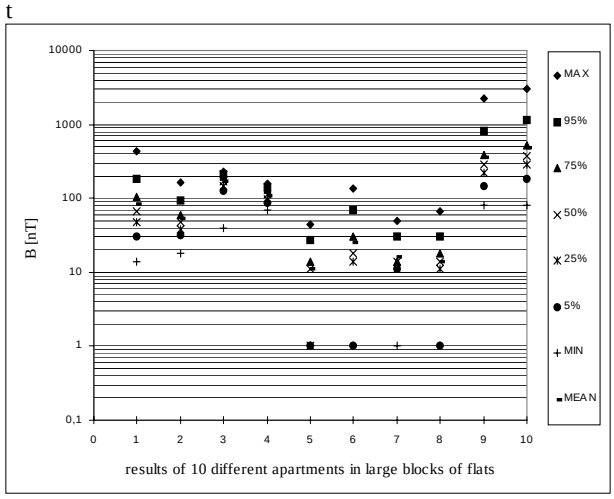

Figure 4: *Magnetic flux density in apartments of different blocks of flats; Measuring duration 24 hours*

than those of detached houses. The arithmetical mean and median reach 400 nT even if the electrical appliances in the flat were switched of. The high values were caused by close transformer station or the location of the main feeders.

4.2 Measuring at working places

Although the main purpose of the study is the investigation of childhood cancer, important aspects of measurement methodology can be learned by looking at similarities and differences between field exposition in flats and at working places.

Numerous measurements were made at working places in various planning- and manufacturing areas. Magnetic fields in flats can be looked at as noise, i.e. many sources superimpose. For that reason, fields can be assessed by mean values or similar mathematical calculation-methods. The fields in working places can often be directly traced to a single piece of machinery. This causes a by far more severe spatial and temporal, variation making the field description more difficult. The amplitude also covers a broad spectrum. Furthermore, harmonics must be taken into account.

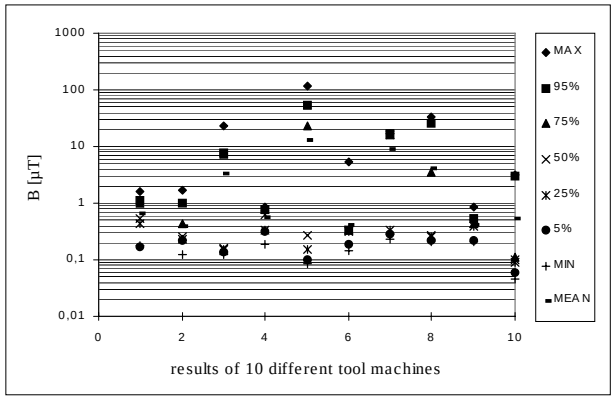

Figure 5: *Magnetic flux density of different tool machines*

4.2.1 Amplitude

The amplitude of low frequency magnetic fields in industry varies strongly. The upper limit was not found out due to the

[1] The median value of all 10 s intervall samples was calculated for each flat. The data shown are the mean value of all N medians.
[2] Standard deviation of all N medians.
[3] The median value of all 30 cm intervall samples was calculated for each flat. The data shown are the mean values of all N medians.

measuring limit of the EMDEX-System of 300 µT. Machines with very high fields were not investigated up to now.

4.2.2 Spatial Dependency

The magnetic fields in industry often show a distinct spatial dependency. The exposition of the workers depends extremely on the place. The field distribution of a machine varies strongly depending on the amplitude of currents flowing in the machine and the way of the currents. A thin approximately infinite straight wire produces a field which follows a 1/r-dependency while two parallel wires produce in a sufficient distance a field with $1/r^2$ dependency. The field of a circular wire (e.g. short coils) fades out with $1/r^3$.

4.2.3 Time-Dependency

Use of machines in the manufacturing field is primarily determined by the production process.

Punching, press and milling machines etc. are connected to the electric power network for short time or at intervals which result in the exposure to magnetic flux densities at working places.

It is unknown whether a noxious effect caused by magnetic fields depends mainly on short-term high intensity (amplitude) or on the mean value of the field exposition.

It is also imaginable that the noxious influence is created by the dosage. In case of dosage the exposure time integral would be responsible for the influence on the biological system.

4.2.4 Harmonics

The induced voltage in the body is often assumed as a risk criterion. The voltage is proportional to frequency, i.e. even if the harmonic content drops by 1/f the harmonics are as important as the magnetic fields of the fundamental frequency.

In industry the harmonic content can be the dominant cause of induction.

Furthermore, a problem is the broad bandwidth of the filter in the EMDEX-System, so its not possible to determine which harmonic dominates.

5. Conclusions

- It exists a weak statistical correlation between the classified types of buildings and the existing magnetic field.
- The exposition values of magnetic flux density in detached houses are generally very low.
- The values of magnetic flux density generally increase as a function of the population density.
- The recorded data in blocks of flats are generally considerable higher because of installed transformers, main feeders and the installation in the flats themselves. Furthermore, the exposition is overlaid by the influence of neighbouring flats.
- In old buildings the exposition depends strongly on the kind of electrical installation.
- Recorded data at working places in industry differ extremely.
- For an exact investigation on the fields in industry a modified measuring system has to be applied, due to the high amplitudes and the harmonics.

The future work will concentrate on finding an improved measuring systematic for the different kinds of buildings in order to get more detailed information on the field exposures.

6. References

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