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Industrial Engineering and Environmental Protection
IIZS conference

PROCEEDINGS

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Zrenjanin, 3rd-4th October 2019.

University of Novi Sad
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RADIATION OF ELECTROMAGNETIC FIELDS OF INDUSTRIAL FREQUENCIES. ELECTROMAGNETIC RADIATION OF ELECTRICAL APPLIANCES IN HOUSEHOLDS

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Abstract: This paper analyzes the sources of time-varying electrical and magnetic fields of industrial frequency. Therefore, very low frequency electromagnetic fields in our environment are analyzed. This refers to the power system, overhead power lines, transformer stations, electrical installations and household electrical appliances. The results of magnetic induction measurements of electrical household appliances (hair dryer, vacuum cleaner, water heater, electric cooker, aspirator, mixer, coffee grinder, mobile charger) are given, depending on the distance from the device.
Key words: fields of industrial frequency, measurements of electrical household appliances

INTRODUCTION

The human environment comprises various sources of non-ionizing radiation. These consider: power lines, cable and satellite communications, power stations, electric transportation vehicles (electric trains, trams and trolleybuses), TV, radio repeaters, etc.. As a result there is an interaction between the electromagnetic fields and biological tissue. The effects of these fields can be harmful to humans if the field strength exceeds certain threshold values which are defined by the corresponding regulations and defined based on harmful effects. In order to analyze the biological effects of electromagnetic radiation and to make assess of the associated hazards in a particular situation, it is necessary to know strength of the field in frequency domain. The same has to be compared with the corresponding allowed value. The field strength values can be reached by applying analytical calculations, numerical methods, or by using the appropriate measurement equipment. Despite the fact that the non-ionizing electromagnetic phenomena have been well studied, interactions between electromagnetic fields and organic matter, and especially human body, are still not fully clarified [1-3].

ELECTROMAGNETIC FIELDS AT VERY LOW FREQUENCIES IN OUR ENVIRONMENT

Time-varying electromagnetic fields generated by time varying AC (Alternating Current) electricity during transmission, distribution and use of electricity. The main sources of time varying electric fields in the work area are electric cables. The strength of these fields is in the range from 1 to 100 V/m. Flow of electrical current through a conductor produces a magnetic field. These fields always form a closed loop around the conductor which caused them. As the basic unit of magnetic flux density Tesla [T] is very large, it is the practice of using smaller units: microtesla [μT] and nanotesla [nT]. Under normal conditions in the workplace time-varying magnetic fields caused by electric grid ranging from 10 nT to 1 mT [2].

Frequency of a VLF field depends on the field sources. Although the dominant frequency of 50 Hz and 60, people are generally exposed to a mixture of frequencies, some of which may be much larger. For example, the frequency of certain parts of electronic equipment or TV monitor can go up to 120 kHz.

In addition, during turning may occur sudden peak in the waveforms of current and voltage, leading to a high-frequency transient conditions that can cause the radiation frequency of a few MHz. Also, the non-linear characteristics of electrical devices can cause the creation of significant harmonics at frequencies of a few kHz. Electric and magnetic fields are components of the EM field. Electric fields are generated in apparatus involved in network installation, ah, these devices do not have to be in operation [4].

Given that the above sources of device components in our environment, we'll just consider these devices as sources of electromagnetic fields of very low frequency VLF. In this sense, we are exposed to VLF magnetic and electric fields originating from many sources: the transmission lines connecting power plants and households through distribution lines and cables that distribute energy into our homes, schools and workplaces, substations, transformers, installation of our homes and buildings, and various other electronic devices.

Electric power system

An electric power system is a network of electrical components used to supply, transmit and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power - for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power - the standard for large-scale power transmission and distribution across the modern world [4,5].
If you look at the picture of a typical power system, (Fig.1) you will recognize come to the conclusion that the transmission system (transmission line) is the main source of the electric and magnetic fields, because of the great length of the conductor and the high voltage line.
But other elements, such as electrical device in industry and households, electrical installations and distribution part of the system, are very important sources of electromagnetic fields in our environment.

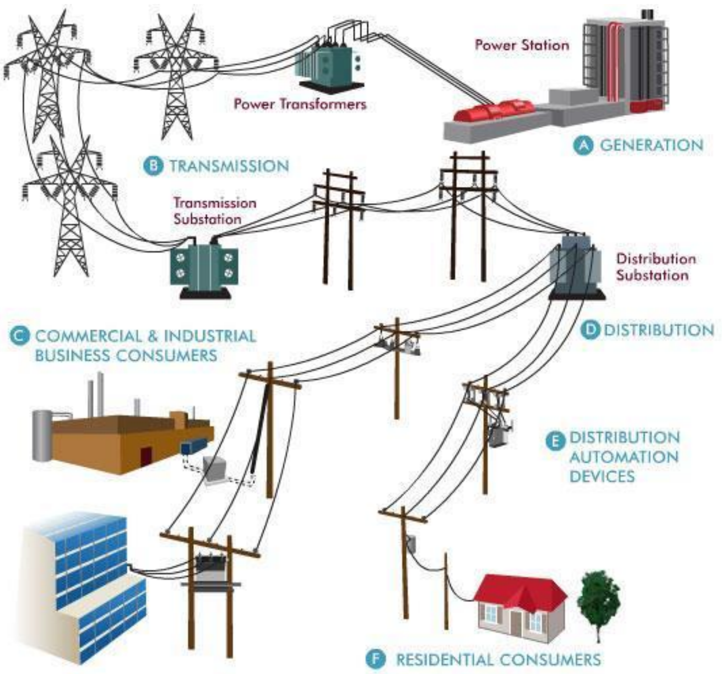


Figure.1. Basic structure of the electric system

Electrical energy produced in power plants is distributed to consumer areas via high voltage power lines from 35 kV to 400 kV. The voltage is reduced by transformers to 400/230 V for local distribution. The general population is exposed to magnetic fields at the network frequency, 50 Hz in as, via three individual sources: high voltage transmission power lines, the local system for the distribution and low voltage electricity at home and at work, and electrical household appliances. The first two sources create basic, so-called background magnetic radiation, known as the magnetic flux density of the environment [4],[5].

Overhead power lines

Transmission and distribution lines can be called by one name - power lines. Overhead power lines (Fig.2.) are the less expensive way to transfer electricity. Usually consist of parallel conductors, which carry most of the energy with very few losses or small radiated energy. Field between the conductors is intense, but it is usually closed between them. The strength of the magnetic field line is determined by the rate of electricity, the proximity of the transmission line, the transmission line height above ground, distance between phases, column geometry and distance from other lines [4],[5].
Highest levels of electric and magnetic field lines are located in the area where the conductors are closest to the earth, and it is midway between the two pillars. Because of the ambient temperature, the height of the lowest conductor was flying lower and higher in the winter, because the levels of the fields in the area flying higher and lower in winter.
Lately, most take account of the distribution and geometry of the column conductors to significantly reduced magnetic field.
At any point the field can be determined by superimposing fields of each wire. If, for example. the three-phase line, then the voltages and currents of each phase conductor to move in, and the resultant field vector calculated based on the sum of the fields of each of the conductors. The only point fields are added which produces a relatively high field strength, while the other points may cancel each other. Conductor fields can thus have a very complex spatial distribution.

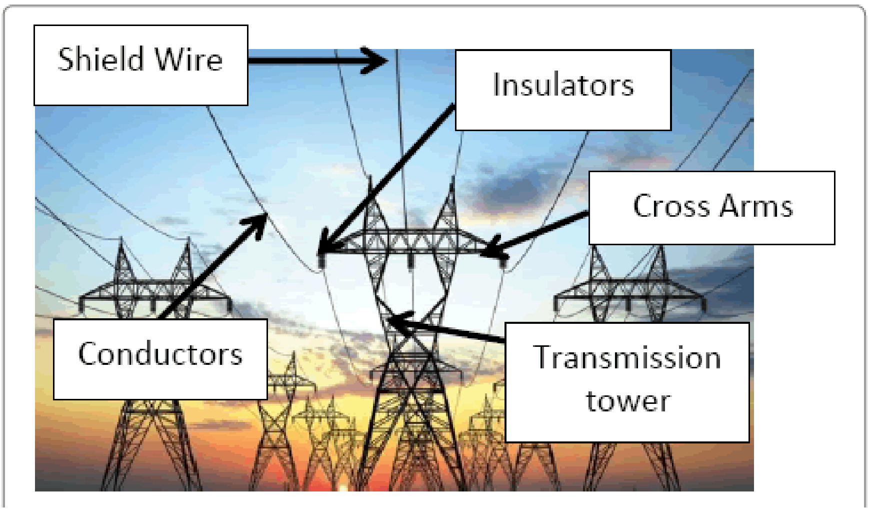


Figure 2. Overhead power lines

Addition to these normal variations in field strength electric field under the conductor is changing depending on their surroundings. In the Fig.3 shown is phenomenon of concentration of the electric field above the person's head beneath the conductors.

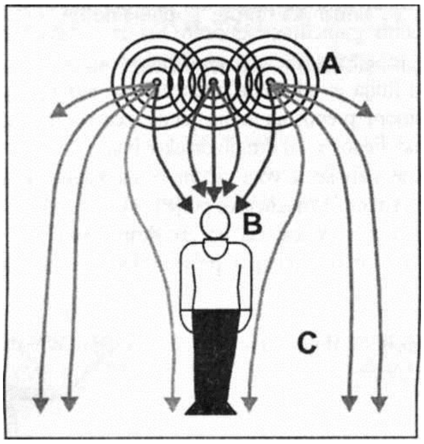


Figure 3. Concentration of the electric field above the person's head beneath the conductors

Because the electric field tends to end up in (or shift to) a grounded object, and because the human body is electrically conductive and near potential electrical field surrounding the Earth is directed toward human head (B). Urinary areas (C) with a weakened electric field strength. All over the world there are vast energy network. That means that almost complete human populations exposed to various fields of power system components. The only difference is in the degree of exposure that varies in the day, days in the week, the season, and depending on the ambient temperature. Most fields are usually located beneath high voltage transmission lines, however, the field strength depends on the strength of the current [4,5].

Transformer stations

Transformer stations (Fig.4) are one of the most important parts of the energy system, which is used to change the voltage level, and perform other functions in the transfer of control and flow of electrical energy. There are several ways to build substations in order to achieve a reliable electricity system. In essence, they are complex equipment such as circuit breakers, high voltage switches, grounding, transformers intended course with the changing voltage control. Since the substations are often located near schools and homes, must be considered as sources close to the electric and magnetic fields.

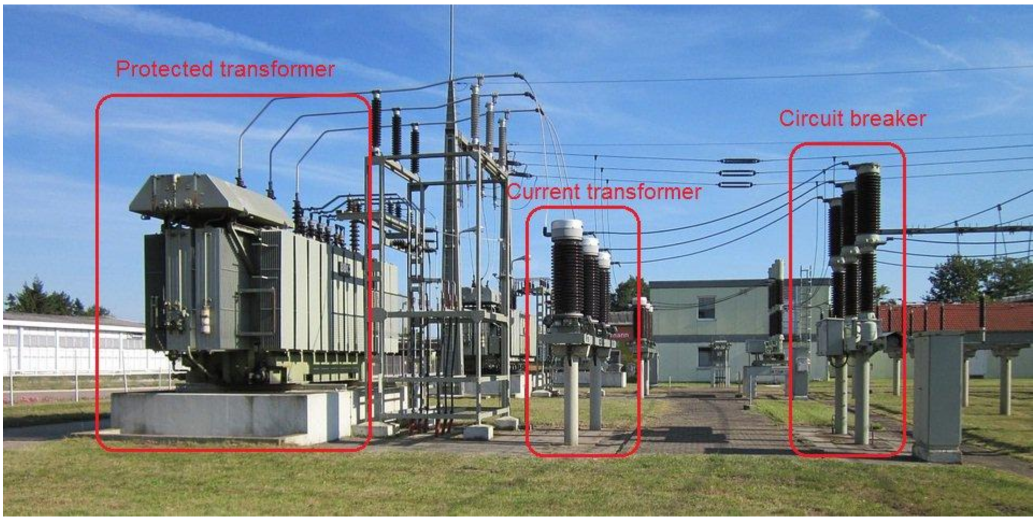


Figure 4. Transformer station

Transformers are sources of strong magnetic fields because their principle of operation is based on a time-varying magnetic fields. The problem of the magnetic field near cells is more complex, since the current entering or leaving the station, in the general case are not symmetric. Field produced by equipment weaks with distance and do not spread outside the physical boundaries stations. However, the magnetic field near the station is stronger than in other parts. Approximate values that can be found near the fence transformer cells depends on the level of voltage: 10 µT for 275-400 kV cells and 1.6 µT station for 11 kV

Transformer as standalone devices found in rural areas (Column transformers), and in urban areas, mostly inside residential buildings. Transformers in buildings adversely affect the people in the apartments above them. These transformers, create an extremely strong electric and magnetic fields. Unfortunately, to enable lower expenses of their installation, they are frequently installed in the buildings. That is not in line with technical recommendation which allowed that kind of installation in exceptional cases, only. This radiation is stronger than transmission radiation [5].

Vehicles on electric power

Electric trams and trains (Fig.5) are also sources of static and VLF fields. For traction they somewhere use direct current somewhere alternating current. Near the coaches floor the static magnetic fields can reach 0.2 mT, and time-varying magnetic fields can reach several hundred µT. At the headquarters of passengers, electric fields can reach up to 300 V / m and magnetic field reaches values of a few tens µT [5].

Figure 5. Radiation Sources in the traffic.

ELECTROMAGNETIC RADIATION ELECTRICAL HOUSE APPLIANCES

Staying in our apartments significantly contributes to the exposure to electromagnetic radiation. All electrical devices, during operation, create a magnetic field. Such fields generally fall inversely with the third degree of distance and are therefore significant at short distances from the device.
In the case of low-frequency radiation measured in the " near zone ", separate measurement of the electric and magnetic fields is required.
At lower frequencies, the magnetic field is more dominant and more harmful to the organism. Therefore, the measurement of the magnetic field H was carried out, depending on the distance from the device.

Figure 6a shows a magnetic dependence diagram of the distance from a mobile charger obtained by measurement, and Figure 6b shows a magnetic dependence diagram of the distance at a coffee mill obtained by measurement. The same results are given in Tables 1 and 2.

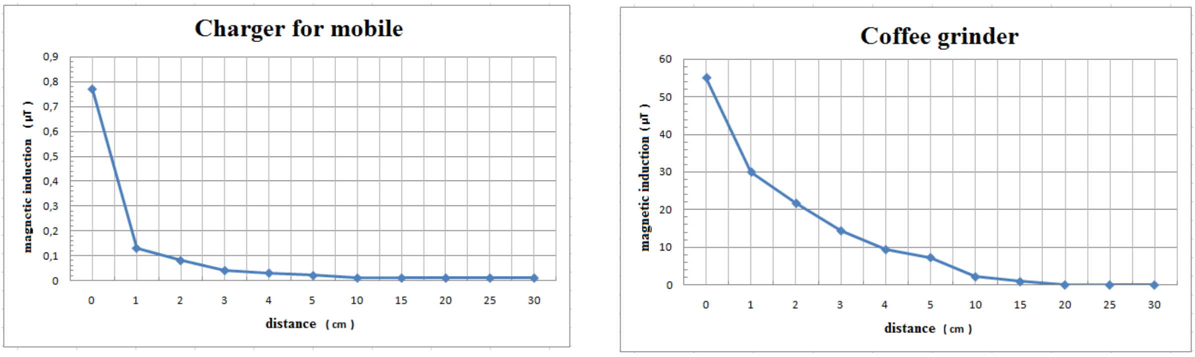


Figure 6. Measured magnetic induction versus distance at a) mobile charger and b) coffee grinder [6].

Table 1. Measured magnetic induction versus distance at mobile charger

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	0,77	0,13	0,08	0,04	0,03	0,02	0,01	0,01	0,01	0,01	0,01

Table 2. Measured magnetic induction versus distance at coffee grinder

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	55	30	21,7	14,4	9,4	7,3	2,2	0,9	0,04	0,02	0,01

Figure 7a shows a magnetic dependence diagram of the distance from a mixer obtained by measurement, and Figure 7b shows a magnetic dependence diagram of the distance at a aspirator obtained by measurement. The same results are given in Tables 3 and 4.

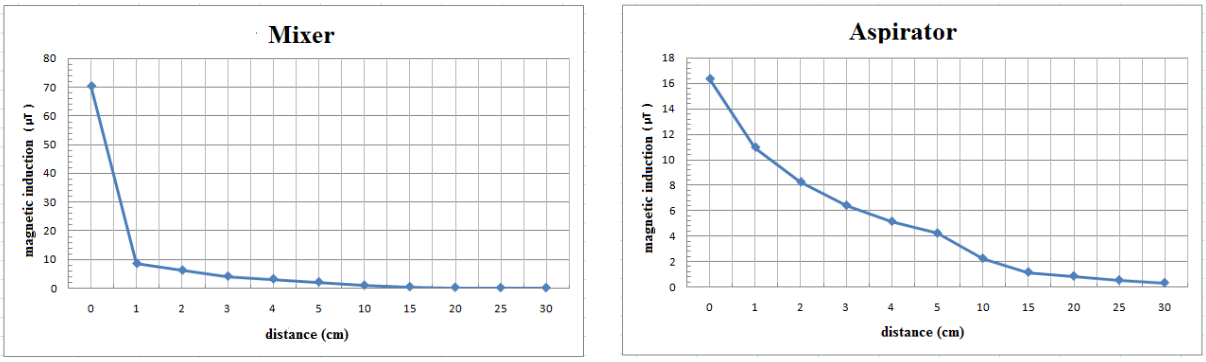


Figure 7. Measured magnetic induction versus distance at a) mixer and b) aspirator [6].

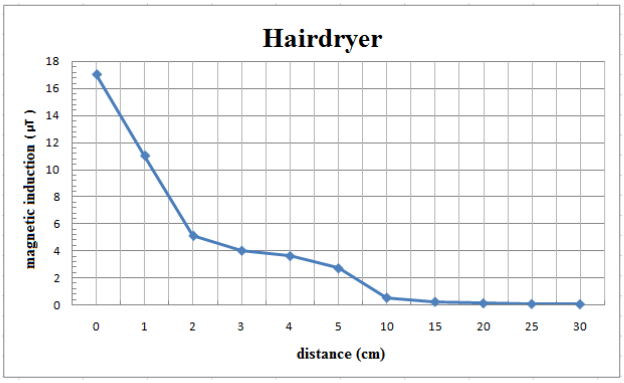
Table 3. Measured magnetic induction versus distance at mixer

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	70,3	8,5	6,15	4,07	3,12	2,07	0,91	0,41	0,17	0,07	0,03

Table 4. Measured magnetic induction versus distance at aspirator

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	16,33	10,95	8,23	6,39	5,13	4,21	2,23	1,15	0,84	0,52	0,31

Figure 8a shows a magnetic dependence diagram of the distance from a hairdryer obtained by measurement, and Figure 8b shows a magnetic dependence diagram of the distance at a vacuum cleaner obtained by measurement. The same results are given in Tables 5 and 6.



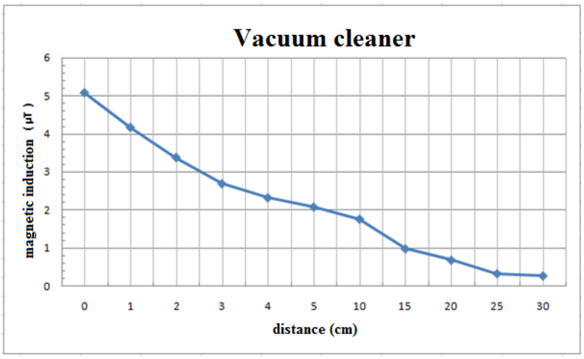


Figure 8. Measured magnetic induction versus distance at a) hairdryer and b) vacuum cleaner [6].

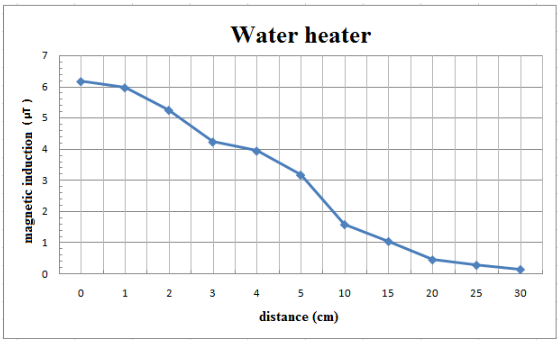
Table 5. Measured magnetic induction versus distance at hairdryer

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	17	11	5,1	4	3,6	2,7	0,53	0,23	0,12	0,07	0,05

Table 6. Measured magnetic induction versus distance at vacuum cleaner

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	5,07	4,16	3,37	2,68	2,31	2,07	1,75	0,97	0,67	0,32	0,26

Figure 9a shows a magnetic dependence diagram of the distance from a water heater obtained by measurement, and Figure 9b shows a magnetic dependence diagram of the distance at a electric stove cleaner obtained by measurement.



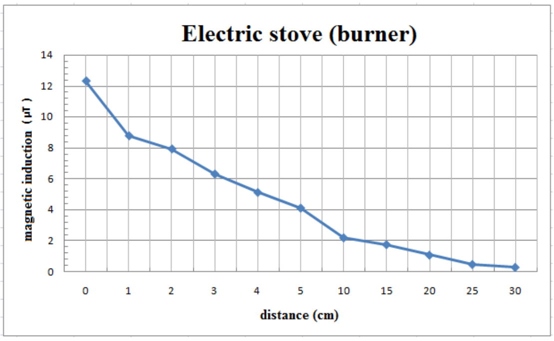


Figure 9. Measured magnetic induction versus distance at a water heater and b) electric stove [6].

Table 7. Measured magnetic induction versus distance at water heater

Distance(cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	6,17	5,97	5,25	4,23	3,94	3,14	1,58	1,04	0,45	0,28	0,14

Table 8. Measured magnetic induction versus distance at electric stove

Distance (cm)	0	1	2	3	4	5	10	15	20	25	30
Magnetic induction (μT)	12,32	8,78	7,93	6,31	5,12	4,11	2,19	1,75	1,07	0,47	0,28

Many workers are more exposed to electromagnetic fields in the workplace than at home, although they spend less time there. Workplace fields are usually larger because of the higher concentration of the device. Electrical devices such as photocopiers can emit strong fields even when in standby mode, while in-use radiation can double.
Some industrial plants have equipment that produces large magnetic fields. In power systems, these are generator buses and some reactive elements in the station.

CONCLUSION

The impact of the electromagnetic field on the health of the broadest population and professionally exposed persons is a problem that has been attracting public attention for over thirty years. Scientists around the world are conducting intensive research into the effects of the electromagnetic field on humans and their environment. So far, the results of studies have not reliably confirmed the direct relationship between low-frequency low-intensity electromagnetic radiation exposure and the number of affected post-mortem populations. However, it is evident that adverse effects exist and depend on field strength, frequency and exposure time, etc. The overall conclusion is that, where possible, unnecessary exposure to these fields should be avoided, necessary safeguards should be taken and the regulations and regulations governing it should be adhered to. The development of technology has led to the application of a large number of devices and systems whose operation is based on the use of electromagnetic fields, so that the density and frequency of radiation in the space in which we live is multiplied. Now the human body is exposed to far higher doses of radiation than was the case with natural sources. Of course, this has some effect on the human body and its health..

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