Physical Characterization of Electromagnetic Energy Absorption of Human Body Tissues

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Abstract—Electromagnetic radiation is emitted by many natural and man made sources and is a fundamental aspect of our lives. We are warmed by electromagnetic radiation emitted from the sun and our eyes can detect the visible light portion of the electromagnetic spectrum. Radiofrequency energy is a portion of the electromagnetic spectrum with frequencies ranging from 3 kHz to 300 GHz, below that of visible light and above that of extremely low frequency electromagnetic energy. The specific biological responses to radiofrequency energy are generally related to the rate of energy absorbed. The rate and distribution of radiofrequency energy absorption depends strongly on the frequency, intensity and orientation of the incident fields as well as the body size and its constitutive properties (dielectric constant and conductivity).

Keywords— Electromagnetic energy; body tissues; frequency; waves; electric current.

I. INTRODUCTION

The extensive use of high frequency currents for heating the deeper tissues of the human body has made it desirable to obtain more information on the path of the current between the electrodes and the distribution of heat in the tissues. The factors which control the current distribution are the relative amounts and positions of the tissues and their specific resistance to the high frequency diathermy current.

In recent years, considerable interest has been shown with regard to the frequencies at which ultrahigh frequency electromagnetic waves produce the most effective therapeutic results [1-6]. Radiofrequency energy is produced by many man made sources including cellular (mobile) phones and base stations, television and radio broadcasting facilities, radar, medical equipment, microwave ovens; radiofrequency induction heaters as well as a diverse assortment of other electronic devices within our living and working environments. It has long been recognized that sufficiently intense radiofrequency energy can cause heating of materials with finite conductivity, including biological tissues. A number of well established biological effects and adverse health effects from acute exposure to intense radiofrequency energy have been documented [4, 6-9]. These effects relate to localized heating or stimulation of excitable tissue from intense radiofrequency energy exposure.

Effects on biological material can be placed in three categories: (1) thermal, (2) specific thermal, (3) nonthermal. Volume heating is the general heating which any type of conductor or semiconductor, such as tissue, may receive under the influence of electrical currents or waves. Specific thermal effects as structural heating exist when boundaries between different types of tissues or particles on a microscopic scale, such as small cell complexes or even bacteria, etc., can be selectively heated without substantial heating of the surrounding material. Those effects, which cannot be explained on a thermal basis, are classified as nonthermal effects [2]. It has been shown that specific thermal effects, such as the selective heating of bacteria, are not possible. The selective temperature rise which a particle may experience by developing internal heating due to absorption of electrical energy is inversely proportional to the square of the particle size.

The interaction of time varying electric fields with the human body results in the flow of electric charges (electric current), the polarization of bound charge (formation of electric dipoles), and the reorientation of electric dipoles already present in tissue. The relative magnitudes of these different effects depend on the electrical properties of the body that is, electrical conductivity (governing the flow of electric current) and permittivity (governing the magnitude of polarization effects). Electrical conductivity and permittivity vary with the type of body tissue and also depend on the frequency of the applied field. Electric fields external to the body induce a surface charge on the body; this results in induced currents in the body, the distribution of which depends on exposure conditions, on the size and shape of the body, and on the body’s position in the field. In the measurement of muscle fiber conduction velocity, the electrode position is crucial for the accurate and reliable recording of myoelectric signals. Several investigators have measured the conduction velocity using surface electrodes [6]. They determined the electrode position based on an anatomical knowledge or on the motor point location found by the electrical stimulation technique [10].
Radiofrequency energy is a portion of the electromagnetic spectrum with frequencies ranging from 3 kHz to 300 GHz, below that of visible light and above that of extremely low frequency electromagnetic energy. The purpose of this range is to establish safety limits for human exposure to radiofrequency electromagnetic energy in the frequency range from 3 kHz to 300 GHz. The safety limits in this range apply to all individuals working at. In a field where technology is advancing rapidly and where unexpected and unique problems may occur, this range cannot cover all possible situations. Consequently, the specifications in this range may require interpretation under special circumstances. The safety limits in this range are based on an ongoing review of published scientific studies on the health impacts of radiofrequency electromagnetic energy. This range is periodically revised to reflect new knowledge in the scientific literature and the exposure limits may be modified, if deemed necessary. Safety factors have been incorporated into these limits to add an additional level of protection for the general public and personnel working near radiofrequency sources.

The absorption of radiant energy is dependent upon the various electrical constants of the individual tissues. Energy absorption leads to the development of heat. This we define as primary heat developed in the irradiated body. Primary heating produces temperature differences between various tissues and even differences within homogeneous material. This happens because primary heat development is most pronounced where the radiant energy is strongest, near the surface to which the radiation is applied. It is also affected greatly by the blood flow, which may carry heat from one body area to another. It is important to realize that heat flow will diminish temperature differences [2]. This means that final temperature distributions are characterized by curves which are flatter than those of primary heat development.

In the measurement of the high frequency electrical resistance of tissues, it is necessary to use alternating current of a frequency of the same order of magnitude as the diathermy frequency, 5 kHz to 300 GHz. With lower frequencies the apparent resistance increases. For this problem we have used a high frequency Wheatstone bridge described in an earlier paper [1]. The absorption electromagnetic energy in electrolytes is rather strong. Therefore, the intensity decreases rapidly. Electrical properties of material are characterized by two constants. They are the dielectric constant or permittivity as it is often called, and the specific resistance. The conductivity of the material is the inverse of the specific resistance. Dielectric constant and conductivity are measures for the two types of current which pass through matter when a unit potential is applied. A capacitive current does not cause any heating, the resistive current does according to Joule’s law.

Indirect effects of electromagnetic fields may result from physical contact (touching or brushing against) between a person and an object, such as a metallic structure in the field, at a different electric potential. The result of contact is the flow of electric charge (contact current) that may have accumulated on the object or on the body of the person. In the frequency range up to approximately 100 kHz, the follow of electric current from an object in the field to the body of the individual may result in the stimulation of muscles and/or peripheral nerves. With increasing levels of current this may be manifested as perception, pain from electric shock and/or burn, inability to release the object, difficulty in breathing and at very high currents, cardiac ventricular fibrillation [11]. Threshold values for these effects are frequency dependent, with the lowest threshold occurring at frequencies between 10 and 100 Hz. Thresholds for peripheral nerve responses remain low for frequencies up to several kHz. Appropriate engineering and/or administrative controls, and even the wearing of personal protective clothing, can prevent these problems from occurring.

Laboratory studies on cellular and animal systems have found no established effects of low frequency fields that are indicative of adverse health effects when induced current density is at or below 10 mA m\(^{-2}\). At higher levels of induced current density (10-100 mA m\(^{-2}\)) more significant tissue effects have been consistently observed, such as functional changes in the nervous system and other tissue effects [12].

### II. ELECTRICAL PROPERTIES OF TISSUE

The electrical properties of tissue and its components are of practical interest in:

**Cardiology:** Knowledge of the dielectric properties of tissues at low frequencies permits analysis of distribution of the currents and potentials generated by the heart.

**Physical Medicine:** Knowledge of the dielectric properties of tissues at ultrahigh frequencies is necessary to understand the mode of action of various forms of diathermy with high frequency currents and electromagnetic radiation.

**Diagnosis:** A number of diagnostic procedures are based on electrical principles.

**Communication:** The effects of strong sources of electromagnetic energy used in radar and some communication techniques on mankind [3].

Of more fundamental importance are studies of the electrical properties of tissue and cell suspensions related to:

1. Structural analysis of cellular organism “properties of cell membranes and cytoplasm”.
3. Analysis of characteristics of protein molecules such as dipole moment, shape, hydration.

The electrical properties of biological material have been studied almost continuously ever since suitable electrical techniques became available for this purpose. Earlier contributions did not help much toward an understanding of the factors responsible for the electrical properties of tissues. This was due to inadequate theory and techniques.

**Absorption Characteristics of Body Tissues**

The electrical properties of matter may be characterized either in terms of an equivalent parallel combination of a conductance and capacitance or a series combination of resistance and reactance. The choice is arbitrary and not indicative of any mechanism. In order to avoid confusion, the
terms conductance and capacitance will be used exclusively with the equivalent parallel combination and the terms resistance and reactance with the equivalent series circuit.

The electrical properties of biological material throughout the total frequency range are due to relaxation phenomena. Molecules which carry a distribution of charges that may be simulated by a dipole will rotate in an alternating field. This rotation is associated with viscous losses and therefore establishes a mechanism for conductance. Since orientation of polar molecules does not occur instantaneously. The force exerted by the field is in competition with forces due to Brownian movement and only partial orientation results. Hence, the degree of orientation increases proportionately with the applied field strength, electrical properties due to polarity of molecules are linear unless saturation effects due to extreme field values are produced. Thus both assumptions necessary for relaxation dispersion (linearity and noninstantaneous response) are fulfilled. The speed of orientation depends, of course, on size and shape of polar molecule, viscosity, and temperature. The characteristic frequency of the dispersion decreases with increase in molecular size and weight [3].

Suspensions of erythrocytes in physiological saline solution provide a good model for the properties of tissue in the radio frequency range. The characteristic frequency changes proportionally with the conductance terms. The electrical properties of fatty tissue have so far not been investigated in detail. However, the frequency dependence is rather smooth in comparison with the muscular data and not indicative of a simple circular behavior in the impedance plane. Further work with this type of tissue must be done to permit a more detailed analysis. Heat development in the body may, be expressed in terms of simple physical quantities. To do so, one must know the dielectric constant and specific resistance of the various body tissues.

Exposure to low frequency electric and magnetic fields normally results in negligible energy absorption and no measurable temperature rise in the body. However, exposure to electromagnetic fields at frequencies above about 100 kHz can lead to significant absorption of energy and temperature increases. In general, exposure to a uniform (plane wave) electromagnetic field results in a highly nonuniform deposition and distribution of energy within the body, which must be assessed by dosimetric measurement and calculation.

As regards absorption of energy by the human body, electromagnetic fields can be divided into four ranges [13]:

- frequencies from about 100 kHz to less than about 20 MHz, at which absorption in the trunk decreases rapidly with decreasing frequency, and significant absorption may occur in the neck and legs,
- frequencies in the range from about 20 MHz to 300 MHz, at which relatively high absorption can occur in the whole body, and to even higher values if partial body (head) resonances are considered,
- frequencies in the range from about 300 MHz to several GHz, at which significant local, nonuniform absorption occurs,
- frequencies above about 10 GHz, at which energy absorption occurs primarily at the body surface.

III. BIOLOGICAL BASIS FOR LIMITTING EXPOSURE

The following paragraphs provide a general review of relevant literature on the biological effects and potential health effects of electromagnetic fields with frequencies of 100 kHz to 300 GHz. Measurement of biological responses in laboratory studies and in volunteers has provided little indication of adverse effects of low frequency fields at levels to which people are commonly exposed. A threshold current density of 10 mA m\(^{-2}\) at frequencies up to 1 kHz has been estimated for minor effects on nervous system functions. Among volunteers, the most consistent effects of exposure are the appearance of visual phosphenes and a minor reduction in heart rate during or immediately after exposure to extremely low frequency (frequency below 300 Hz) fields, but there is no evidence that these transient effects are associated with any long term health risk. A reduction in nocturnal pineal melatonin synthesis has been observed in several rodent species following exposure to weak extremely low frequency electric and magnetic fields, but no consistent effects has been reported in human exposed to extremely low frequency fields under controlled conditions [5]. Studies on both direct and indirect effects of electric, magnetic and electromagnetic fields are described; direct effects result from direct interaction of fields with the body, indirect effects involve interactions with an object at a different electric potential from the body. Results of laboratory and epidemiological studies, basic exposure criteria, and reference levels for practical hazard assessment are discussed, and the guidelines presented apply to occupational and public exposure.

A. Direct Effects of Electromagnetic Fields

Interpretation of several observed biological effects of amplitude modulated electromagnetic fields is further complicated by the apparent existence of windows of response in both the power density and frequency domains. There are no accepted models that adequately explain this phenomenon, which challenges the traditional concept of a monotonic relationship between the field intensity and the severity of the resulting biological effects. Overall, the literature on thermal effects of amplitude modulated electromagnetic fields is so complex, the validity of reported effects so poorly established, and the relevance of the effects to human health is so uncertain, that it is impossible to use this body of information as a basis for setting limits on human exposure to these fields.

Even though it can be shown that, except for special cases, the hope for a selective distribution of high frequency energy among various organs cannot be realized; still the stratified structure of biological tissues is important for another reason. The microscopic layer structure of the cell groups and of the
single cells exerts a strong influence on the distribution of the energy in the irradiated tissue [6].

### B. Indirect Effects of Electromagnetic Fields

In the frequency range of about 100 kHz to 110 MHz, shocks and burns can result either from an individual touching an ungrounded metal object that has acquired a charge in a field or from contact between a charged individual and a grounded metal object. It should be noted that the upper frequency for contact current (110 MHz) is imposed by a lack of data on higher frequencies rather than by the absence of effects. However, 110 MHz is the upper frequency limit of the frequency modulation broadcast band. Threshold currents that result in biological effects ranging in severity from perception to pain have been measured in controlled experiments on volunteers [11, 14-16]; these are summarized in Table I. In general, it has been shown that the threshold currents that produce perception and pain vary little over the frequency range 100 kHz to 1 MHz and are unlikely to vary significantly over the frequency range up to about 110 MHz. As noted earlier for lower frequencies, significant variations between the sensitivities of men, women, and children also exist for higher frequency fields. The data in Table I represent the range of 50th percentile values for people of different sizes and different levels of sensitivity to contact currents.

**TABLE I. RANGES OF THRESHOLD CURRENTS FOR INDIRECT EFFECTS, INCLUDING CHILDREN, WOMEN, AND MEN**

<table>
<thead>
<tr>
<th>Threshold current (mA) at frequency</th>
<th>Indirect effect</th>
<th>100 kHz</th>
<th>1 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Touch perception</td>
<td></td>
<td>25-40</td>
<td>25-40</td>
</tr>
<tr>
<td>2 Pain on finger contact</td>
<td></td>
<td>33-55</td>
<td>28-50</td>
</tr>
<tr>
<td>3 Painful shock/let go threshold</td>
<td></td>
<td>112-224</td>
<td></td>
</tr>
<tr>
<td>4 Severe shock/breathing difficulty</td>
<td></td>
<td>160-320</td>
<td></td>
</tr>
</tbody>
</table>

### C. Biological Effects and Epidemiological Studies

Many laboratory studies with rodent and nonhuman primate models have demonstrated the broad range of tissue damage resulting from either partial-body or whole-body heating producing temperature rises in excess of 1-2°C. The sensitivity of various types of tissue to thermal damage varies widely, but the threshold for reversible effects in even the most sensitive tissues is greater than 4 W kg$^{-1}$ under normal environmental conditions. These data form the basis for an occupational exposure restriction of 0.4 W kg$^{-1}$, which provides a large margin of safety for other limiting conditions such as high ambient temperature, humidity, or level of physical activity. Both laboratory data and the results of limited human studies [17-19] make it clear that thermally stressful environments and the use of drugs or alcohol can compromise the thermoregulatory capacity of the body. Under these conditions, safety factors should be introduced to provide adequate protection for exposed individuals.

Data on human responses to high frequency electromagnetic fields that produce detectable heating have been obtained from controlled exposure of volunteers and from epidemiological studies on workers exposed to sources such as radar, medical diathermy equipment, and heat sealers. They are fully supportive of the conclusions drawn from laboratory work, which adverse biological effects can be caused by temperature rises in tissue that exceed 1°C. Epidemiological studies on exposed workers and the general public have shown no major health effects associated with typical exposure environments. Although there are deficiencies in the epidemiological work, such as poor exposure assessment, the studies have yielded no convincing evidence that typical exposure levels lead to adverse reproductive outcomes or an increased cancer risk in exposed individuals. This is consistent with the results of laboratory research on cellular and animal models, which have demonstrated neither teratogenic nor carcinogenic effects of exposure to thermal levels of high frequency electromagnetic fields [5]. Exposure to pulsed electromagnetic fields of sufficient intensity leads to certain predictable effects such as the microwave hearing phenomenon and various behavioral responses. Epidemiological studies on exposed workers and the general public have provided limited information and failed to demonstrate any health effects. Reports of severe retinal damage have been challenged following unsuccessful attempts to replicate the findings.

A large number of studies of the biological effects of amplitude modulated electromagnetic fields, mostly conducted with low levels of exposure, have yielded both positive and negative results. Thorough analysis of these studies reveals that the effects of amplitude modulated fields vary widely with the exposure parameters, the types of cells and tissues involved, and the biological end-points that are examined. In general, the effects of exposure of biological systems to thermal levels of amplitude modulated electromagnetic fields are small and very difficult to relate to potential health effects. There is no convincing evidence of frequency and power density windows of response to these fields.

### D. Maximum Exposure Limits

During this time, a significant number of new studies have evaluated the potential for acute and chronic radiofrequency energy exposures to elicit possible effects on a wide range of biological endpoints including: human cancers (epidemiology); rodent lifetime mortality; tumor initiation, promotion and co-promotion; mutagenicity and DNA damage; EEG activity; memory, behaviors and cognitive functions; gene and protein expression; cardiovascular function; immune response; reproductive outcomes; and perceived electromagnetic hypersensitivity among others. Numerous authoritative reviews have summarized this literature [20-30].

Despite the advent of thousands of additional research studies on radiofrequency energy and health, the predominant adverse health effects associated with radiofrequency energy exposures in the frequency range from 3 kHz to 300 GHz still relate to the occurrence of tissue heating and excitable tissue stimulation from short term (acute) exposures. At present, there
is no scientific basis for the premise of chronic and/or cumulative health risks from radiofrequency energy at levels below the limits outlined in specific absorption rate. Proposed effects from radiofrequency energy exposures in the frequency range between 100 kHz and 300 GHz, at levels below the threshold to produce thermal effects, have been reviewed. At present, these effects have not been scientifically established, nor are their implications for human health sufficiently well understood. Additionally, a lack of evidence of causality, biological plausibility and reproducibility greatly weaken the support for the hypothesis for such effects. Thus, these proposed outcomes do not provide a credible foundation for making science based recommendations for limiting human exposures to low intensity radiofrequency energy.

For frequencies from 100 kHz to 300 GHz, tissue heating is the predominant health effect to be avoided. Other proposed nonthermal effects have not been conclusively documented to occur at levels below the threshold where thermal effects arise. Studies in animals, including nonhuman primates, have consistently demonstrated a threshold effect for the occurrence of behavioral changes and alterations in core body temperature of $\pm 1.0^\circ C$, at a whole body average specific absorption rate of $\pm 4$ W/kg [7–9]. To ensure that thermal effects are avoided, a safety factor of 10 has been incorporated for exposures in controlled environments, resulting in a whole body averaged specific absorption rate limit of 0.4 W/kg. A safety margin of 50 has been incorporated for exposures in uncontrolled environments to protect the general public, resulting in a whole body averaged specific absorption rate limit of 0.08 W/kg.

The basic restrictions which shall not be exceeded are given in terms of the currents in the body, either by induction or contact with energized metallic objects, or in terms of the rate at which radiofrequency electromagnetic energy is absorbed in the body. In practice, direct measurements of specific absorption rate are only feasible under laboratory conditions. Therefore, recommended maximum exposure levels in terms of unperturbed electric and magnetic field strength as well as power density are given in addition to the specific absorption rate limits. These maximum field intensities are at levels that ensure that the specific absorption rate or induced body current will be no greater than that of the basic restrictions. Additional factors such as temporal variations in intensity and spatial distribution of the exposure fields are accounted for by provisions for time and spatial averaging. Exposure to radiofrequency energy in excess of the limits given in this safety code, when time and spatially averaged may cause adverse health effects. The specific absorption rate should be determined for situations where exposures occur at a distance of 0.2 m or less from the source. In cases where specific absorption rate determination is feasible, the values in Table II shall not be exceeded.

### IV. DISCUSSION

The occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. By contrast, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals. In many cases, members of the public are unaware of their exposure to electromagnetic fields. Moreover, individual members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underlie the adoption of more stringent exposure restrictions for the public than for the occupationally exposed population.

There is insufficient information on the biological and health effects of electromagnetic fields exposure of human populations and experimental animals to provide a rigorous basis for establishing safety factors over the whole frequency range and for all frequency modulations. In addition, some of the uncertainty regarding the appropriate safety factor derives from a lack of knowledge regarding the appropriate dosimetry [31, 32]. The following general variables were considered in the development of safety factors for high frequency fields:

- effects of electromagnetic fields exposure under severe environmental conditions (high temperature, etc.) and/or high activity levels,
- the potentially higher thermal sensitivity in certain population groups, such as the frail and/or elderly, infants and young children, and people with diseases or taking medications that compromise thermal tolerance.

The following additional factors were taken into account in deriving reference levels for high frequency fields:

- differences in absorption of electromagnetic energy by individuals of different sizes and different orientations relative to the field,
- reflection, focusing, and scattering of the incident field, which can result in enhanced localized absorption of high frequency energy.

Administrative controls, such as limitations on access and the use of audible and visible warnings, should be used in conjunction with engineering controls. Personal protection
measures, such as protective clothing, though useful in certain circumstances, should be regarded as a last resort to ensure the safety of the worker; priority should be given to engineering and administrative controls wherever possible. Furthermore, when such items as insulated gloves are used to protect individuals from high frequency shock and burns, the basic restrictions must not be exceeded, since the insulation protects only against indirect effects of the fields.

With the exception of protective clothing and other personal protection, the same measures can be applied to the general public whenever there is a possibility that the general public reference levels might be exceeded. It is also essential to establish and implement rules that will prevent: (1) interference with medical electronic equipment and devices (including cardiac pacemakers), (2) detonation of electro-explosive devices (detonators), (3) fires and explosions resulting from ignition of flammable materials by sparks caused by induced fields, contact currents, or spark discharges.

The specific biological responses to radiofrequency energy are generally related to the rate of energy absorbed. The rate and distribution of radiofrequency energy absorption depends strongly on the frequency, intensity and orientation of the incident fields as well as the body size and its constitutive properties (dielectric constant and conductivity). The characteristic peculiarities of the behavior of biological tissues in the ultra short wave region lie in the elementary (microscopic) division of the high frequency energy in the biological system (cell groups, blood, colloidal suspensions, etc.). The significance of this microscopic tissue structure is expressed by the marked wavelength dependence of the high frequency conductivity and dielectric constant of the tissue, which always conforms, as experimentally demonstrated with the individual physical and anatomical characteristics.

The electrical properties of tissue and suspensions of biological cells show a pronounced dispersion at low frequencies. This dispersion is more sensitive to age and environmental factors than the other dispersion and displays a dispersion of different origin. Various possibilities exist to explain this behavior. From these, three deserve major consideration:

1. A gating mechanism, controlling metabolic exchange and involving a time delay between stimulus and response (applied potential and current). This explanation places emphasis on the difference between static and dynamic permeability. The difference between these two quantities is of comparable magnitude for lysed erythrocytes, muscle cells, and the axon of the squid. Observed large differences in membrane capacitance frequency dependence are explained by relaxation theory and due to variation in speed of response. They are not of primary interest since in this model; capacitance has no material significance and is simply a measure of the reactive properties which the gates must display.

2. Structure of the cellular membrane.

3. Surface conductance due to ionic atmospheres around the cells causing relaxation. The unknown quantity in this case is the value of the surface conductance. Measurements with solid particles show that the phenomena of dispersion is not restricted to biological cells with membrane structure [3].

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Dr. Burhan Davarcioglu, Hacettepe University, Ankara-Turkey, Faculty of Engineering in 1978, enters as the Engineer graduated from the Physics. Nuclear Medicine Department in the years 1984-1985 at Hacettepe University, Radiation Physics and Radioisotope Laboratories has participated in the creation work. 1985-1993 Research Fellow in the years of working as a Gazi University, Institute of Science and Technology, Department of Physics, in 1987, “Solid-State Lasers” with his Master’s thesis, and in 1992, “Some Complex and Clathrates Infra-red Spectroscopy Investigation” of the named PhD thesis completed. Faculty Member appointed as Dr. Davarcioglu, Nigde University in 1994, took active part in the founding. Faculty of Arts and Sciences Department of Physics and Institute of Science and Technology the establishment of many administrative tasks found. Turkish National Committee on Clay Science is member and New York Academy of Sciences is an active member. Papers presented at the international level to the majority and the broadcast Dr. Davarcioglu’s many references were made to run. Of interest related to the study of various summer schools participated. Since the year 2000, industrial raw materials quality and quantity of clay, by means of the spectroscopic identification of the work operates. Aksaray University, was appointed in April of 2007 to the relay.