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USSR REVIEW OF BOOK ON HIGH-FREQUENCY HEATING OF DIELECTRICS AND SEMICONDUCTORS

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The book Vysokichastotnyy nagreb dielektrikov i poluprovodnikov (High-Frequency Heating of Dielectrics and Semiconductors), by A. N. Maznin, A. V. Netushil, and Ye. P. Parini, (Gosenergoizdat, 1950, 236 pages, 13.75 rubles), contains ten chapters, an appendix, a bibliography, and an alphabetical index. It presents an account of basic phenomena underlying the high-frequency heating of dielectrics and semiconductors. Elementary information is given on the theory of high-frequency vacuum-tube oscillators. Oscillator circuits applicable to dielectric heating are discussed, and several industrial equipments are described. Basic relationships for the calculation of vacuum-tube oscillators, as well as instructions on their utilization, are given. The book is intended for use by electrical engineers and production engineers who must deal with high-frequency equipments for dielectric heating.

Chapter 1 is devoted to the importance of high-frequency heating of dielectrics and semiconductors in industry. The history of the problem is stated, with emphasis on the priority of Soviet researchers in this field. The branches of industry in which high-frequency heating is used are pointed out. Mentioned very briefly are some technological characteristics of high-frequency heating of various substances (drying of wood, preheating of plastics, high-frequency heating in the rubber industry, etc.).

Chapter 2 gives elementary information on electrostatics. The electric field of a parallel-plate condenser is discussed. Such terms as capacitance, electric field intensity, breakdown voltage, and energy of an air-dielectric capacitor are defined and the relations between these values are given. Polarization of conductors, semiconductors, and dielectrics in an electric field are discussed. The concepts of polarizable and polar molecules in dielectrics are

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presented. The relationship between polarization and field intensity is derived. The concept of dielectric constants is outlined. Formulas are given for calculating the energy and energy density of the electric field in a dielectric. The different nature of polarization in dielectrics and in semiconductors is noted. The charge distribution in a semiconductor at different stages of polarization is described.

Chapter 3 discusses heating of materials in an alternating electric field. The liberation of heat in conductors when an electric current flows in them and the liberation of heat in conductors placed in an alternating electric field are both discussed. Formulas are given for computing the electrical power converted to heat in the material; examples are used to illustrate that very little heat is liberated in conductors within an alternating field because of their very low resistivity. Transfer of electrical energy from source to load is described and the concept of skin effect is presented; the dependency of depth of current penetration upon resistivity and frequency is given.

Chapter 3 also includes a discussion of the generation of heat in dielectrics placed in an alternating electric field. The theory of dielectric losses is presented in very elementary form. It is indicated that the basic cause of heat generation within the dielectric is the friction which takes place between polar molecules and between these molecules and the adjacent stationary particles. These concepts are illustrated by graphs of tg δ versus frequency, temperature, and moisture content for various dielectrics.

Finally, Chapter 3 contains a discussion of heat generation in semiconductors placed in an alternating electric field. Since semiconductors possess properties characteristic of both conductors and dielectrics, energy losses of both kinds occur. At low frequencies, a semiconductor behaves like a conductor, while at high frequencies the dielectric properties become most prominent. The concept of equivalent electric circuit of a semiconductor is introduced, on the basis of which formulas are given for calculating conductance, susceptance, effective resistance, and reactance of semiconductors (g,b,r, and x). By way of illustration, graphs give the dependence of ε, tg δ, g, b, r, and x, upon frequency, moisture content, and temperature for some semiconductors.

In Chapter 4, instances of nonuniform heating of materials are discussed and the conditions by which this nonuniformity can be obviated are set forth.

As an example, the distribution of temperature and moisture in nonhomogeneous samples of wood during the drying process is given. Using the graphs of the preceding chapter, the authors demonstrate that, in the case of transversely alternating wood layers with different initial moisture content, a greater amount of heat will be generated within layers of 10% moisture content than in those having 5% moisture content; i.e., more heat is generated in the more humid layers, while if the alternating layers contain 15% and 40-50% of moisture, respectively, more heat is generated within the drier layers. This is explained by the fact that at 10% moisture content, the curve of r, in the case of spruce, passes through a maximum, and since the specific power p is proportional to r, p also reaches a maximum at that moisture content.

The heating in the case of a longitudinal distribution of the material layers within the electric field is discussed. It is shown that in this instance the specific power is proportional to the conductivity, and that the more humid layers are heated to a greater extent.

The effect of an air gap between material and electrode is pointed out. By simple mathematical computations, the authors show that the existence of an air gap results in unsatisfactory heating conditions in the case of wood containing more than 15-20% moisture (temperature distribution is inversely proportional to moisture). In high-frequency drying of wood, therefore, the

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existence of an air gap between wood and electrode is to be avoided. (Members of the Electric Heating Section of VNITOE did not agree with the authors' contention that it is undesirable to have an air gap in the operating condenser when subjecting wood to high-frequency drying.) Heating of anisotropic materials is discussed. Graphs are given showing the conductivity and effective resistance for birch in different directions of the anisotropy axes as a function of moisture content. It is shown that nonuniform temperature distribution within the wood in the high-frequency heating process is caused by the heterogeneous structure of the wood.

Heat generation in materials which fill the condenser in an uneven manner is considered. Illustrations are given showing the temperature distribution within bodies of various configuration when placed in condensers of different shapes. The shape of a condenser producing uniform heating is ascertained.

A discussion follows on nonuniform heating due to formation of standing waves. The formation of standing waves is explained, and the conditions under which they occur are stated. The authors recommend that the distance between the point of supply connection and the most remote point of the dielectric should not exceed 1/20 of the wave length. If this condition is maintained, the nonuniformity of the electric field will not exceed 5%. Systems for the compensation of standing waves (by means of parallel supply of the load and connection of tuned inductances) are given in those instances where, because of production conditions, high frequency is required in heating dielectrics of large size. The chapter is concluded by a brief description of dielectric heating in a cavity resonator when waves of the meter and decimeter band are used.

Chapter 5 considers the material being heated from the standpoint of generator load. Formulas are given for calculating effective resistance and reactance of the charge depending upon the specific characteristics of the material and the degree of filling of the condenser by the material being heated. Some systems for compensating the changes in load parameters in the heating process are discussed. Numerous systems of electrode arrangements are given: for the cementing of variously shaped parts, for the heating of films and filaments, for the drying of thin layers of materials, for the thawing out of soil, for conveyer heating of materials, etc. Formulas are given for calculating the energy and power theoretically required for various types of heat-treatment. Graphs are supplied for determining the heat of fusion and evaporation of various substances depending on the speed required in the process and weight of the material. Formulas are given for calculating the power necessary to compensate for heat losses into the surrounding medium and graphs are given showing the relation between thermal losses (by convection and by radiation) and surface temperature of the material. Examples are given at the end of the chapter for computing the power required, taking thermal losses into account.

Chapters 6, 7, and 8 are devoted to the theory of vacuum-tube oscillators. Free oscillations in the case of theoretical and actual circuits are considered and methods of producing damped and undamped high-frequency oscillations (spark, electric machine, and vacuum-tube generators) are treated.

Construction, operation, and characteristics of electron tubes are described. Oscillator tubes of various designs (air- and water-cooled) and a magnetron used for the generation of oscillations having a frequency greater than 220 Mc are discussed.

The operation of a separately excited generator under conditions of first- and second-order oscillations is discussed. The concept of intensity of generator operating conditions is introduced and systems of parallel and series plate supply are treated. Instructions are given for selection of generator tubes and design of the generator.

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Next, the operation of self-excited generators is considered. Conditions of self-excitation and various feedback systems are given. In addition the following topics are discussed: systems for obtaining grid bias, push-pull operation, oscillators with two tuned circuits, and coupling of tuned curcuits. Also, resonance curves of two coupled circuits are given for various values of the coupling coefficient. Generator power supplies are discussed, in particular the operation of A. N. Larionov's gas-filled rectifier.

In conclusion, some of the operational characteristics of short-wave and ultrashort-wave generators are very briefly presented.

Chapters 9 and 10 deal with industrial high-frequency heating installations. Operational characteristics of industrial vacuum-tube generators are discussed. Methods of matching load and efficiency for generators with one and two tuned circuits are described. Systems of automatic load matching and automatic resonance tuning are given.

Systems and descriptions of industrial vacuum-tube generators are then presented, specifically the following:

1. The high-frequency installation with two GKE-1000 tubes in push-pull developed by TsNILEPS (Central Scientific Research Laboratory for the Electrification of Industry and of Construction Work) for the preheating of molding powders; power of 1.5 kw, frequency, 25-35 Mc; the installation makes it possible to heat 100-120 g of standard molding material up to 120-140 °C within 30-40 seconds.

2. Diagram and description of the installation for the drying of wood, also developed by TsNILEPS, with two G-454 tubes; oscillatory power of 50 kw; frequency 333, 476, and 666 kc.

Chapter 11, the last chapter, deals with the adjustment and operation of industrial installations. This chapter covers operations which must be carried out when adjusting and testing the installation and putting it into operation. Methods of eliminating parasitic oscillations are discussed. Descriptions are given of instruments and methods of measuring used in adjustments; e.g., measurement of high-frequency current, voltage, and power. Methods of reducing interference to radio reception are discussed, and standards for permissible industrial radio interference caused by industrial high-frequency installation are cited. The chapter is concluded by rules for maintenance and safety procedures.

The appendix contains an example showing the calculations involved in designing a 1.6-kw vacuum-tube generator for the heating of molding powders.

The book is undoubtedly of interest, since it is the first attempt to present in a systematic manner the theoretical and experimental data presently available in the field of dielectric heating.

Pamphlets and articles published recently on high-frequency heating of dielectrics and semiconductors deal only with specific and isolated phases of this extensive and complex problem. In this book, an attempt is made to provide a general review of all available data. However, apparently because of its limited size, the book covers only a small portion of data (mostly experimental) accumulated up to now by the personnel of various industrial enterprises and scientific research establishments.

Nevertheless, the task undertaken by the authors -- to present in the simplest possible manner the basic phenomena underlying the high-frequency heating of nonmetallic materials, and to outline the functioning and the elements of design of vacuum-tube generators of high-frequency oscillations, -- has been for the most part fulfilled.

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There is some doubt as to whether the material of chapters 2, 3, and 4 has been presented in a sufficiently comprehensive manner. These chapters dealing with the fundamentals of dielectric heating are schematic and formally mathematical in presentation. In striving for an elementary explanation of these phenomena, the authors have very much oversimplified their physical meaning.

Although the preface states that production peculiarities and engineering economic factors of high-frequency heating are to be treated by the authors in separate publications, the economic aspects of high-frequency heating should have been given definite consideration in this book. At present, there is an excessive enthusiasm for dielectric heating, and large expenditures are frequently made on researches where the prospect of success is obviously nonexistent. Hence, there should have been included in the book (which had a sufficiently large printing and undoubtedly will reach a wide circle of readers) an objective evaluation, from the economic standpoint, of the various technological applications of high-frequency heating.

In describing generators with a single tuned circuit, the authors assert (page 182) that over-all efficiency of the installation may reach 60-70%. Such figures might mislead the reader and convey a false impression as to the actual efficiency of the installation. As a matter of fact, the efficiency of industrial installations at present is only 35-40%. The authors neglect heat losses from the material being heated, and clearly underestimate losses in filament and grid circuits and in the rectifier.

In describing systems of industrial vacuum-tube generators, the authors merely discuss installations developed by TsNILEPS, without mentioning whether they have been put into production.

At the same time, the authors fail to describe installations Lg-3 and LGD-10 which have been accepted for mass production, or the type GS-48 installation for the drying of wood which is now manufactured by the Plant imeni Voroshilov.

In conclusion, it must be admitted that in spite of the short-comings noted, the book is undoubtedly useful not only to those for whom it is intended, but also to those concerned with planning, building, and reasearch in the field of dielectric heating. Its publication is timely.

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