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ices. Several typical applications are described in the following paragraphs.

One of the earliest applications of magnetic type recorders for an announcement system was made in New Jersey in 1937 to give potato growers up-to-the-minute information regarding prices, car movements, loadings, and holdings. To receive this information it was necessary to call a listed number and, since the installation was in manual central-office area, the operator completed the call via a jack to the announcement bus. The system employed two machines, one in service, and the other being held as a spare or for new recordings.

A management announcement system, used on a few trial installations, permits the management of large corporations to disseminate important information to certain groups of employees without these employees leaving their regular work locations. The information is recorded on a magnetic-type machine and interested employees call a number in the company private-branch exchange to hear this announcement. Since it is often necessary to make a new recording without interrupting service, two machines are provided. These machines can also be operated sequentially if a particularly long announcement is needed.

It is planned to provide arrangements at the New York Stock Exchange to give price quotations on some of the most active stocks. The brokers will be able to obtain the latest price by dialing the number listed for the particular stock. The quotations on the announcement machines will be constantly kept up-to-date by recordings from attendants at the trading posts on the floor.

Magnetic-type recorders were also used in a large New York newspaper office in 1937, not as an announcement system but as recording devices. In this instance, reporters out on assignments, could go to the nearest telephone, call their office and be connected to a recorder on which they would record their reports for later transcription.

There have been other special applications of voice recording equipment, including railroad-reservation information.[2]

Future Development

As far back as the late 1920's it was found that recorded announcements would serve to expedite service as applied to the Call Announcer. This experience indicated that voice recording was a valuable tool in communications. As seen from the foregoing descriptions, a number of other applications have been made with resulting advantages in convenience and services rendered to both subscribers and operating personnel.

At the present stage, various other applications are being explored, more are anticipated within the next few years, and indications are that this field should become increasingly important in the years ahead.

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No Discussion

Heating of Fat-Muscle Layers by Electromagnetic and Ultrasonic Diathermy

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IN CLINICAL practice, it is frequently desirable to produce heat in the muscular tissue which lies below subcutaneous layers of fat. Until recently short-wave diathermy provided the most satisfactory answer to the general problem of deep heating. However, biophysical research[1] has shown that, when electric currents pass through alternate layers of fat and muscle, the fatty tissue is selectively heated. Although the ratio of heat developed in fat to that in muscle becomes smaller as the frequency increases, even at the highest practical frequencies the ratio is still greater than unity. It was in part to overcome this difficulty that electromagnetic and ultrasonic radiation were introduced as forms of diathermy following the second World War. The heating of homogeneous tissues by radiant energy has previously been discussed.[2] However, the important fat-muscle problem as it applies to the new forms of radiation diathermy has not, up to now, been given quantitative consideration.

Radiation Diathermy

The discussions for heat development in the case of electromagnetic and acoustic radiation are completely analogous. In both cases, radiant energy flows through the tissue and is, in part, absorbed and converted into heat. At the interfaces separating two different tissues, reflections occur giving rise to standing waves which may materially influence the pattern of heat development. In order to obtain a complete analytical description of this problem it will only be necessary to assume knowledge of the complex propagation constants γ which characterize the various media. These propagation constants in turn, are either directly measurable quantities or can be simply related to measurable quantities. The quantitative conclusions of this analysis depend, therefore, upon measurements of the electromagnetic and acoustic properties of the tissues involved. Sources of these data are discussed in subsequent sections.

For the present discussion the conditions found in the body will be idealized, as shown in Fig. 1. Plane waves are assumed incident normally on plane and parallel interfaces, which separate the

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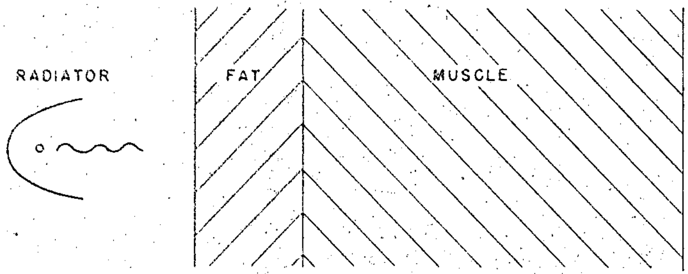

Fig. 1. One-dimensional representation of the fat-muscle configuration as found in the body

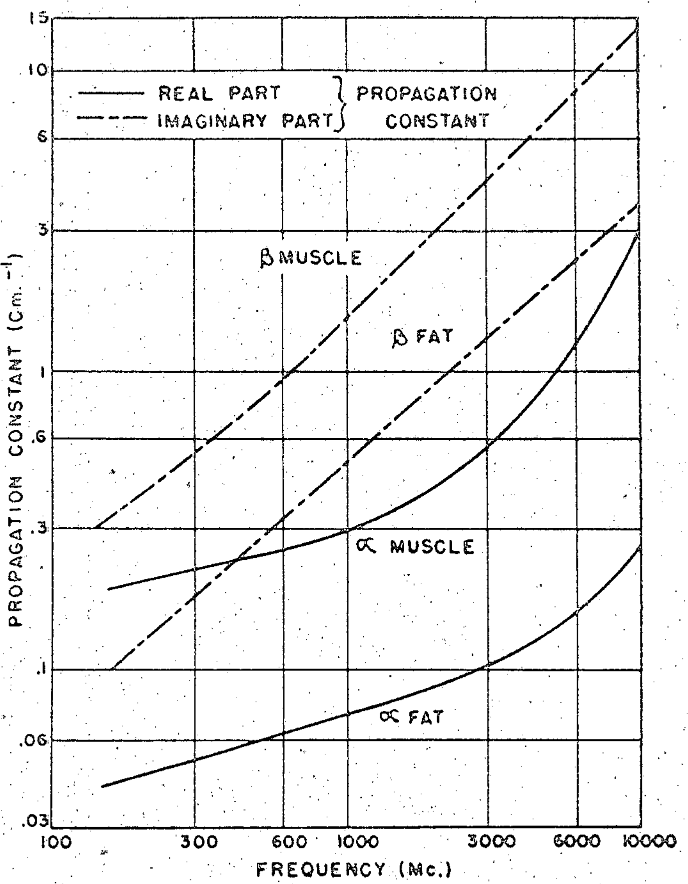

Fig. 2 (right). Electromagnetic propagation constant $\gamma=\alpha+j\beta$ for fat and muscle

layer of subcutaneous fat from the coupling medium (for example, water or air) on one side, and from the semi-infinite region of muscular tissue on the other side. The fat layer is taken to have a thickness d; the layer of muscle is assumed so thick that the waves transmitted into it are completely absorbed. This assumption is justified for most practical cases in view of the high absorption coefficient of muscle tissue, as shown in Figs. 2 and 4. The origin of the space co-ordinates is taken at the fat-muscle boundary and reference fields are defined at this point. For simplicity, the reference field E_0 will be taken as the effective incident wave at the fat-muscle boundary $x=0$. Of course, the effective incident wave is the sum of the initial wave transmitted directly from the generator and all positively directed reflection arising within the fatty layer. However, it can be shown[3] that the reflection factor for this sum is the same as for a single wave. Hence the complete picture can be given in terms of the effective incident wave.

In the following, the symbol E will be used for the electric field in the electromagnetic case, or for excess pressure in the acoustic case, while H will be used interchangeably for magnetic field or particle velocity. The field in fat then consists of incident and reflected waves E_1 and E_2.[4,5]

$$E_f=E_1+E_2=E_0(e^{-\gamma_f x}+pe^{\gamma_f x})$$

$$H_f=H_1+H_2=\frac{\gamma_f}{j\mu_f\omega}(e^{-\gamma_f x}-pe^{\gamma_f x})$$

where

μ = permeability in electromagnetic case and density in the acoustic case
p = the complex reflection factor of the fat-muscle boundary
γ = the propagation constant

The time factor $e^{j\omega t}$ is implied throughout. By applying the boundary conditions[4,5] it is seen that

$$p=\rho e^{j\varphi}=\frac{\dfrac{\gamma_f}{\mu_f}-\dfrac{\gamma_m}{\mu_m}}{\dfrac{\gamma_f}{\mu_f}+\dfrac{\gamma_m}{\mu_m}} \qquad (1)$$

The subscripts f and m refer to fat and muscle, respectively. In the electromagnetic case, where it is reasonable to assume $\mu_f=\mu_m=1$ this reduces to the following

$$p=\frac{\gamma_f-\gamma_m}{\gamma_f+\gamma_m}$$

The wave transmitted into the muscle is characterized by

$$E_m=(1+p)E_0e^{-\gamma_m x}$$

$$H_m=(1-p)\frac{\gamma_m}{j\mu_m\omega}E_0e^{-\gamma_m x}$$

The intensity I, or energy flow per unit area of the beam, is given by the complex product of electric and magnetic fields, complex Poynting's vector, in the electromagnetic case and by the complex product of pressure and particle velocity in the acoustic case.

Writing $\gamma=\alpha+j\beta$ and using $p=\rho e^{j\varphi}$, the intensity in fat is

$$I_f=\frac{1}{2}EH^*=\frac{1}{2}\frac{\beta_f+j\alpha_f}{\mu_f\omega}E_0E_0^*\times$$
$$[e^{-2\alpha_f x}-\rho^2e^{2\alpha_f x}+j2\rho\sin(2\beta_f x+\varphi)]$$

The asterisk is used to signify the complex conjugate of the number.

The rate of development of heat per unit volume is given by the negative space rate of change of the real part of this intensity,[4] that is,

$$-\frac{\partial}{\partial x}\operatorname{Re}I_f=\frac{1}{2}\frac{2\alpha_f\beta_f}{\mu_f\omega}E_0^2\times$$
$$[e^{-2\alpha_f x}+\rho^2e^{2\alpha_f x}+2\rho\cos(2\beta_f x+\varphi)] \qquad (2)$$

In the electromagnetic case, this reduces to

$$\frac{1}{2}\kappa_f E_0^2[e^{-2\alpha_f x}+\rho^2e^{2\alpha_f x}+2\rho\cos(2\beta_f x+\varphi)]$$

where κ_f is the electrical conductivity of fat, since the product $\alpha_f\beta_f=(\mu_f\kappa_f\omega)/2$.

From the continuity of E across the

Table I. Dielectric Constant ϵ of Various Tissues at Different Frequencies

Tissue	Frequency, Megacycles 100	300	1,000	3,000	10,000
Muscle	74.0	60.0	54.0	54.0	45.0
Horse fat	8.0	7.1	5.6	4.4	3.3
Pork fat	5.2	4.6	3.4		

Table II. Resistivity ρ of Various Tissues at Different Frequencies

Tissue	Frequency, Megacycles 100	300	1,000	3,000	10,000
Muscle	100	100	86	45	8
Horse fat	1,550	1,350	1,100	850	380
Pork fat	3,800	3,150	2,450		

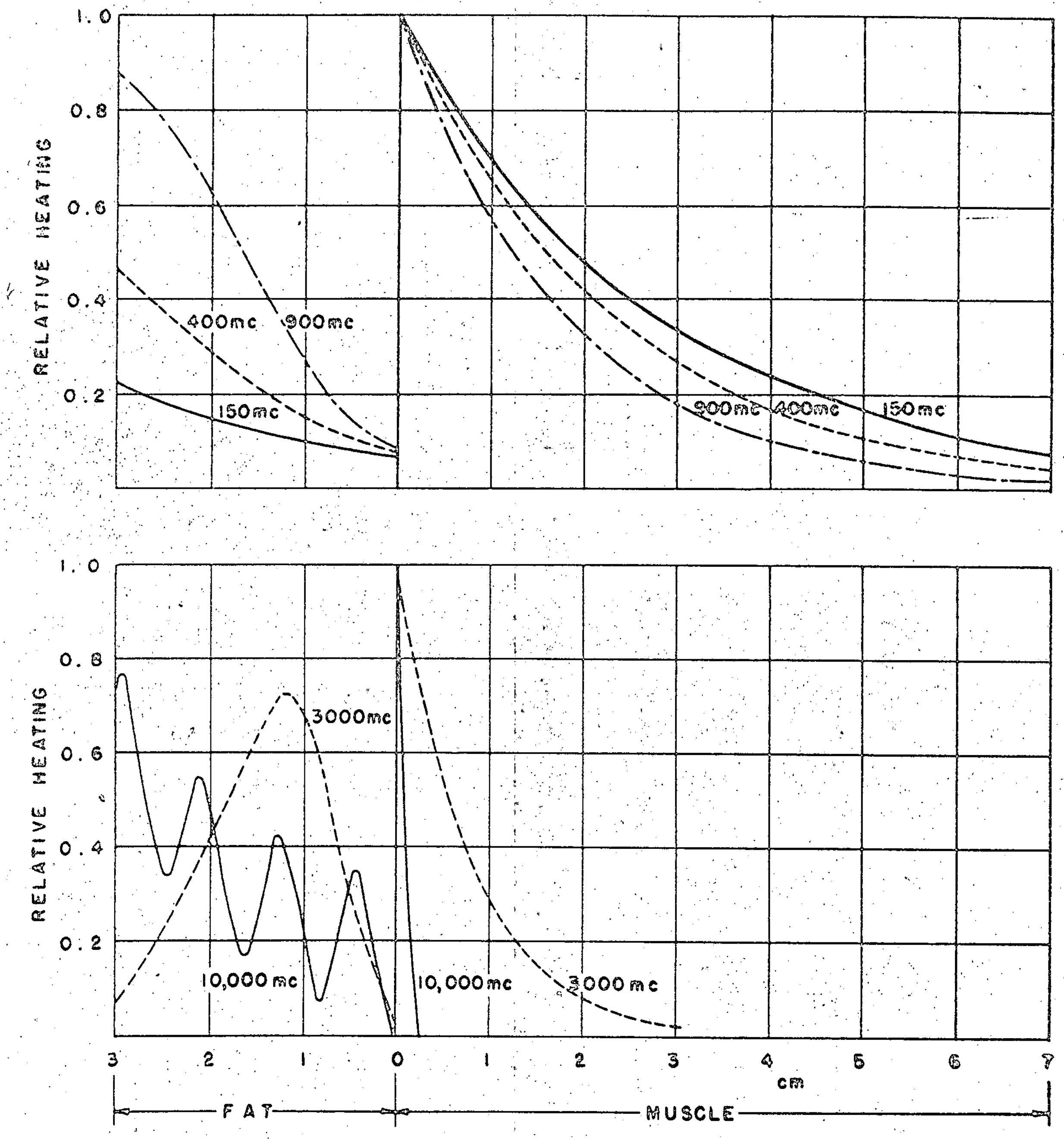

Fig. 3. Heat development per unit volume in electromagnetic case. All values are relative to heat development in muscle at the interface

interface, it follows that

$$-\frac{\partial}{\partial x}\mathrm{Re}I_m=\frac{\alpha_m\beta_m}{\mu_m\omega}E_0^2(1+\rho^2+2\rho\cos\varphi)e^{-2\alpha_m x} \tag{3}$$

Electromagnetic Diathermy

Dielectric studies have been carried out above 1,000 megacycles[6-8] and below 100 megacycles[9] for various body tissues. In addition, blood has been investigated[10] in the range 100 to 1,000 megacycles. The mechanism of absorption of electromagnetic energy is well enough understood[11] to be able to state that all tissues with high water content will have properties similar to that of blood in the 100 to 1,000-megacycle range. To complete the picture for fatty tissue, it was necessary to measure the dielectric constant and resistivity of fat in the range 100 to 1,000 megacycles. The methods of measurement will be reported elsewhere. The relative dielectric constant and resistivity in ohm-centimeters for horse and pork fat and muscle are summarized in Tables I and II. Although muscle impedance is remarkably uniform, the range of values for various kinds of fat is of the order of a factor of two. All measurements were obtained at temperatures near 37 degrees centigrade with fresh tissue samples. The data for the water-rich horse fat are used for the numerical calculations which follow.

The propagation constant can be written in terms of these data as

$$\gamma=j(2\pi/\lambda)\sqrt{\epsilon^+}$$

where

$\epsilon^+=\epsilon'-j\epsilon''$ is the complex dielectric constant
$\epsilon'=$ the relative dielectric constant
$\epsilon''=60\lambda_0\kappa$
$\lambda_0=$ the electromagnetic wave length in air
$\kappa=$ the electrical conductivity

Values of the attenuation constant α and the phase constant β for horse fat and muscle are given in Fig. 2. From these values it is possible, using equations 2 and 3, to predict the heat development as a function of depth of tissue for a fat-muscle configuration such as shown in Fig. 1.

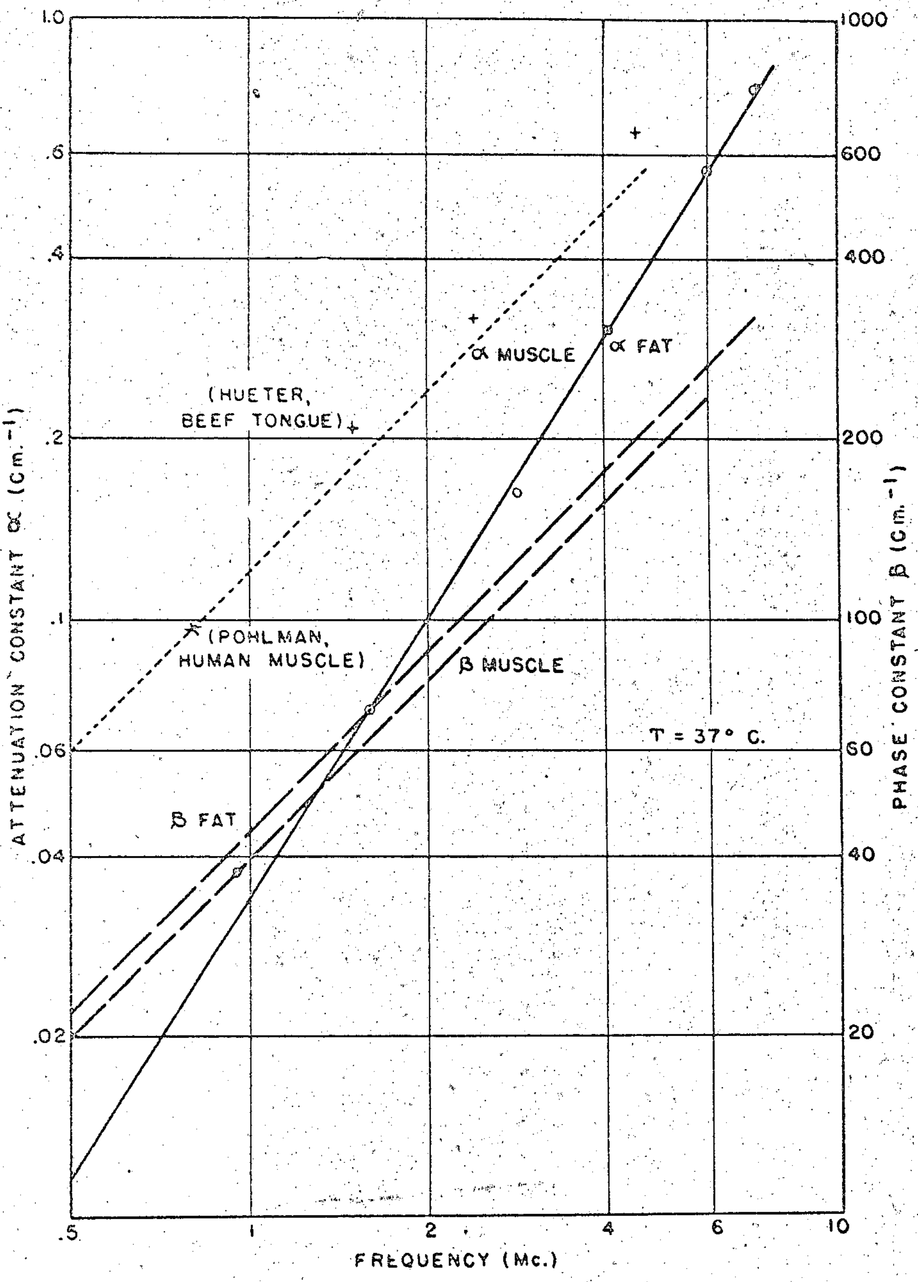

Fig. 4. Acoustic propagation constant $\delta = \alpha + j\beta$ for fat and muscle

The results for frequencies 150 megacycles to 10,000 megacycles are presented in Fig. 3. All values are plotted relative to the heat development in the muscle at the fat-muscle interface. In the electromagnetic case, the reflection factor is high. The magnitude ρ varies from 0.5 to 0.6 throughout the frequency range. This gives rise to a marked standing wave pattern which is predominantly important in determining the heating pattern in the fatty layer. The phase angle is roughly 180 degrees, which tends to minimize heat development in fat near the boundary. It is apparent that the lower frequencies are indicated for a high depth of penetration of energy into the muscle and low heating of the fatty layer. The advantage of radiation diathermy is illustrated by the fact that even at 3,000 megacycles, where the depth of penetration in muscle is very small, it is still possible to get some energy into the first centimeter of the muscle layer even though it is covered by as much as 2 centimeters of fat. The curves, however, show that lower frequencies are much more effective in providing deep heating.

Ultrasonic Diathermy

In the acoustic case, free-field methods are ordinarily used to determine the propagation constant directly. Comparatively little information is available in literature regarding the ultrasonic properties of tissue. Hueter[12] has shown that the absorption of muscle tissues is a linear function of frequency. Pohlman[13] gives a value for the absorption coefficient of human muscle at 800 kc. For the absorption constant of muscle α_m in Fig. 4, a linear curve has been drawn through Pohlman's 800-kc value. Also shown are Hueter's values for beef tongue. Other muscle tissues which he measured have higher absorption coefficients. Ludwig[14] gives the value 1.68×10^5 centimeters per second for velocity of sound in beef muscle.

Essentially no information is available in the literature on the acoustic properties of fatty tissue. To carry out this study, measurements of the absorption and velocity of sound were conducted on fresh pork fat. The corresponding propagation constants for temperatures of 37 degrees centigrade are given in Fig. 4. It will be noted that the absorption in fat has approximately a 1.5 dependence upon frequency in the range from 1 to 7 megacycles. Since depths of penetration of the order of 4 centimeters are desirable for deep heating the frequency range near 1 megacycle is indicated for ultrasonic diathermy.

The density of the fatty tissue used in the measurements was approximately 0.93. Ludwig[14] gives a value of 1.06 for the density of muscle tissue. From these data and the propagation constants it follows, by equation 1, that only roughly 2 per cent of the incident energy is reflected at a fat-muscle interface in the acoustic case. Furthermore, the wavelength is of the order of 1 millimeter; hence any spatial fluctuations of heat development caused by standing waves would be so close together that they would be smoothed out by heat conduction. Using the values given in Fig. 4, the heat development for a fat-muscle configuration is computed by equations 2 and 3, and presented in Fig. 5, for frequencies of 1 megacycle and 2 megacycles.

Conclusions

Perhaps more important than heat development per unit volume is the total rate of heat development in the fatty layer, as compared with that in the muscle. This information is obtained simply by integrating equations 2 and 3. With thickness of the fatty layer as a parameter, the ratio of heat developed in a layer of fat to that in a semi-infinite region of muscle is shown for the electromagnetic case in Fig. 6 and for the ultrasonic case in Fig. 7.

If it is arbitrarily assumed desirable to generate at least three times as much heat in the muscle as in the fat, then frequencies of roughly 500 megacycles in the

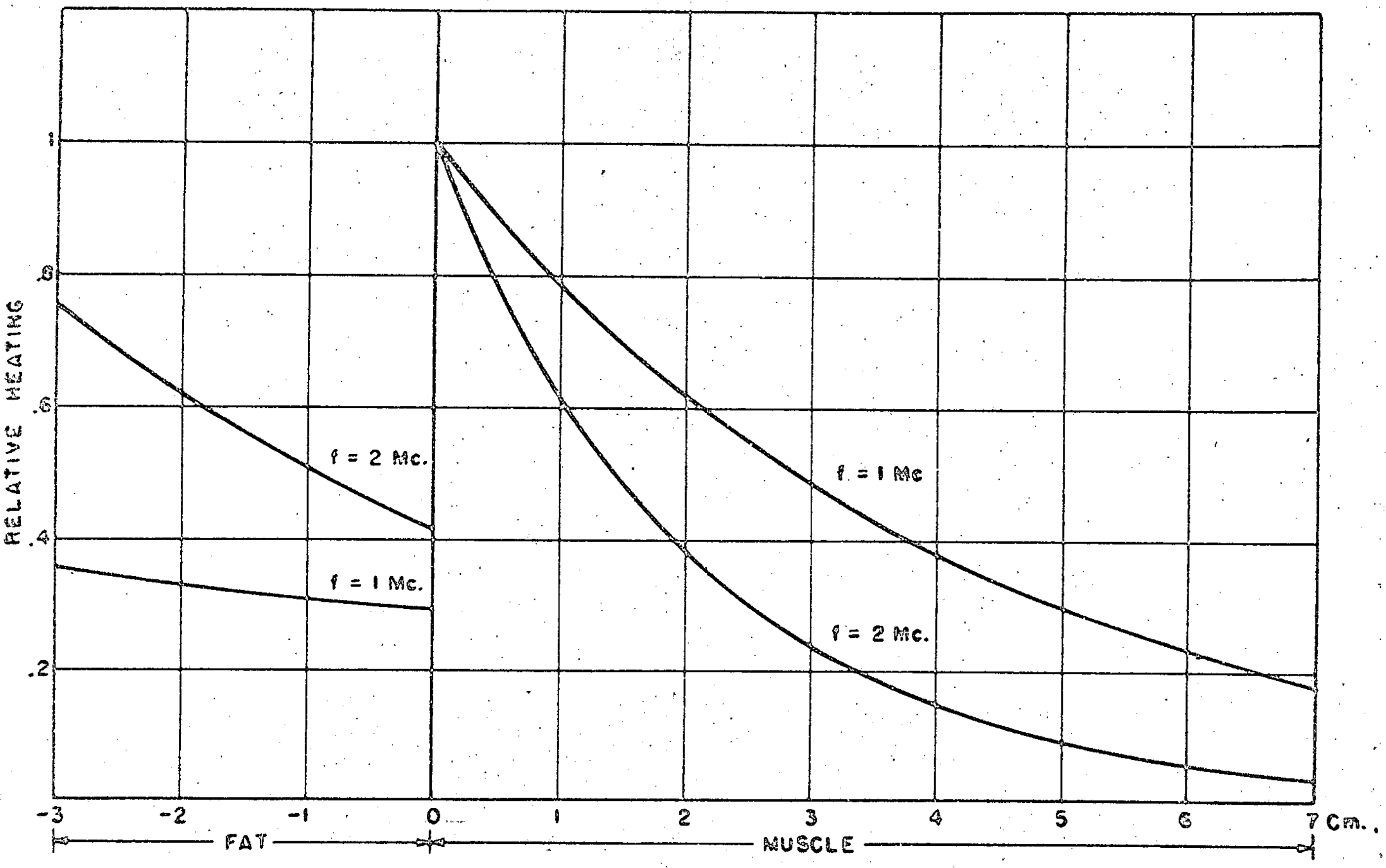

Fig. 5. Heat development per unit volume in the ultrasonic case. (All values are relative to heat development in muscle at the interface)

electromagnetic case and 1 megacycle in the ultrasonic case should be used. In short-wave diathermy the ratio of heat developed in fat to that in muscle decreases with increasing frequency. Just the opposite is true for radiation diathermy, where lower frequencies are recommended for selective heating of muscle. With short-wave diathermy, the fatty layer in a series fat-muscle configuration is always selectively heated. However, with both forms of radiation diathermy it is possible, by proper choice of frequency, to penetrate the fatty layer and dissipate a large fraction of the total energy in the underlying muscle.

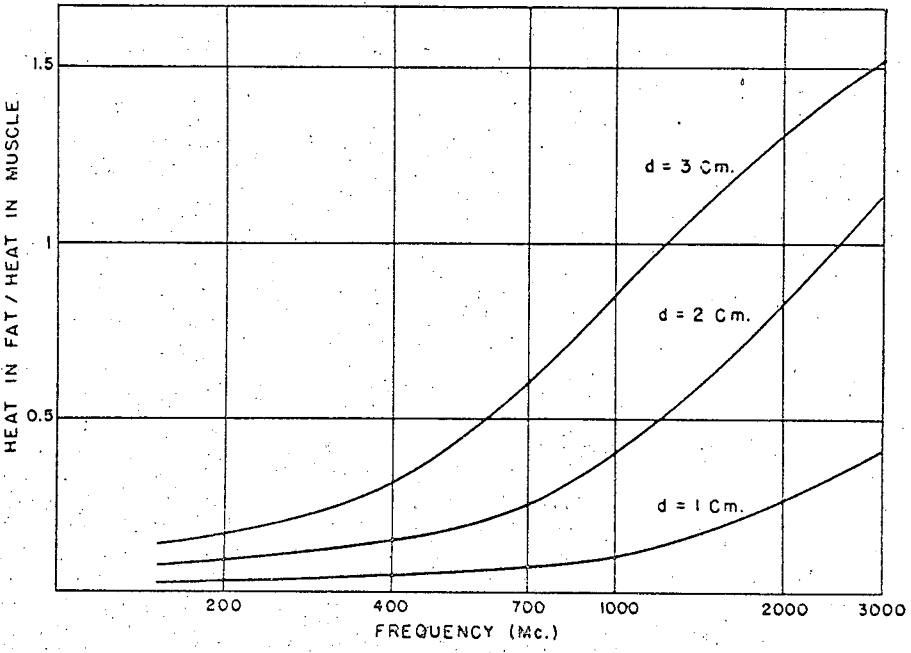

Fig. 6. Relative heat generation in fatty layer versus that in muscle; electromagnetic case

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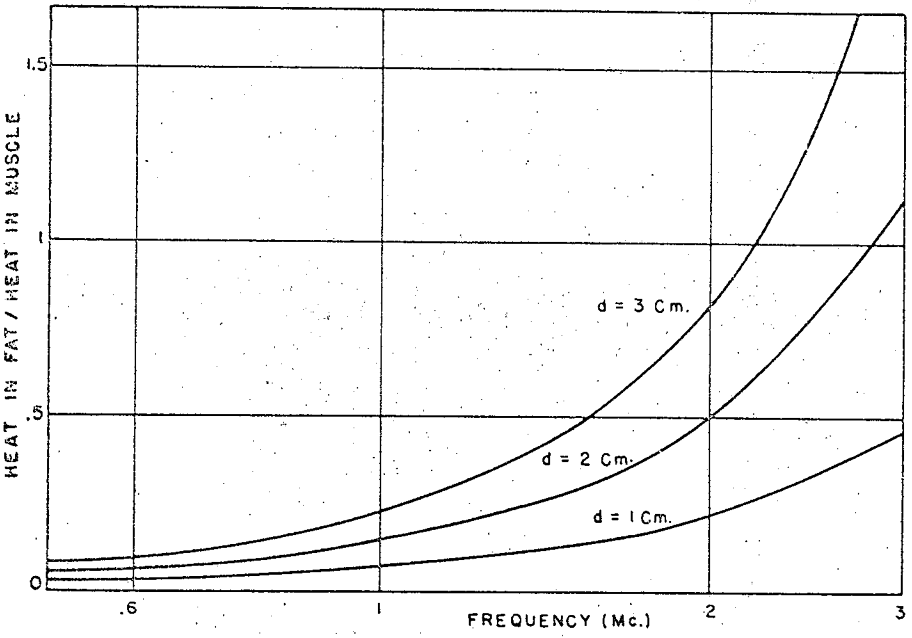

Fig. 7 (left). Relative heat generation in fatty layer versus that in muscle; ultrasonic case

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No Discussion

Problems to Consider in Applying Selenium Rectifiers

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THE PROPER selection of selenium rectifier stacks for d-c power supplies in large scale industrial or military projects usually requires considerably more information than can be obtained from a manufacturer's catalog. The most important problem in applying selenium rectifiers arises in connection with the life requirements for the application. Test data indicate that the life expectancy of selenium rectifiers is affected by the different manufacturing techniques used by the suppliers. With the present art of manufacture, the life expectancy tends to decrease as the cell voltage rating is increased. In addition, the life is affected by the current density and the temperature at which the selenium cells are operated.

The selection of selenium rectifier stacks for use in d-c power supplies involves several important considerations, as follows:

1. Circuit requirements must be carefully analyzed so that allowances may be made for variations in the voltage-current characteristics of each manufacturer's product, as well as for variations that exist for the same stacks processed by different manufacturers.

2. The equipment engineer must anticipate the differences in mechanical details of the same stack assembled by different suppliers. Unfortunately, there is no standardization in the selenium industry regarding mechanical details such as the over-all length and height of the stack, and particularly the type of mounting.

3. The engineer must take into account the magnitude of the changes in the voltage-current characteristics of the rectifier stacks over the specified temperature range of his project. At very low temperatures, output voltages may be 5 to 10 per cent lower than at normal room temperatures. For high-temperature operation, the stacks must be properly derated for both current and voltage, to prevent overheating and rapid failure.

4. Unless otherwise specified, rectifier stacks are coated with various types of paints and varnishes for protection against moisture in normal conditions of humidity. For military projects and other applications where selenium rectifiers may be exposed to high humidities, fungus, salt, or other corrosive atmospheres, the rectifier stacks must be provided with a more suitable type of protective coating or finish. These finishes are available from most manufacturers.

5. Selenium rectifiers age with time. Compensation for this aging should be provided if load requirements warrant. The project engineer should determine what life he expects or requires of the application. For military applications life requirements may vary from minutes to thousands of hours. On other applications, such as telephone and elevator installations, it is desirable to design selenium rectifiers for life expectancies of 10 to 20 years or more.

Electrical Ratings

The electrical ratings of selenium rectifiers are based on their voltage, current, and thermal characteristics. All three of these characteristics must be considered carefully for initial design purposes, as any one can affect life expectancy.

VOLTAGE RATINGS

The voltage rating is usually expressed as the reverse voltage rating. It is the maximum rms sine-wave voltage above which an excessive reverse current would flow and overheat the cell, causing breakdown. However, the important consideration establishing the rating is the peak voltage applied to the cell. If the applied voltage differs significantly from a sine-wave, it is important that the peak voltage shall not exceed 1.41 times the rated rms voltage.

When selenium cells were originally manufactured in this country, their rms voltage ratings ranged from 14 to 18 volts. Ratings later increased to 26 volts, and at the present time the goal appears to be 33 volts or higher. One manufacture has already successfully produced 33-volt cells for several years. An-

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