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The Elements of Induction and Dielectric Heating

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Pledge:
On my honor I have neither given nor received unauthorized aid on this paper.

Robert E. Gearhart

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Abstract

The uses of induction and dielectric heating in industry has become very important. These methods of generalizing heat in the material itself have many distinct advantages over the conventional methods of heating

Induction heating uses an inductor coil to set up a magnetic field around a metallic substance. When these currents encounter resistance, heat is produced. Dielectric heating makes use of alternating current at high frequencies to generate heat in nonmetallic masses.

Obtaining the high frequencies at which these heaters operate is an important problem. The present use and the future uses of these two types of heating is manifold.

Precedes T of C

The Principles and Applications of Induction and Dielectric Heating

Preface

On a recent tour of various industries in northeastern Pennsylvania, I became interested in the use of the dielectric heater. The particular industry using the dielectric heater was "Laminated Products, Inc.". After a tour of their plant, I found myself wondering how this heater operated and for what other uses it could be designed. In my research on the subject of dielectric heaters, I came across induction heating-the counterpart of dielectric heating in metallic substances-and realized that the principle and applications of these two types of heating, along with electronic frequency changing which is necessary for this type heating, would be the basis of an excellent paper.

previous papers on file (reference to?)

Introduction

The principles of induction and dielectric heating present an interesting study in the field of electronics. The bountiful applications of these two types of heating prove their present value to industry. The method of attaining the high-frequency necessary for the operation of induction and dielectric heaters demonstrates the usefulness of the electronics of today.

A few definitions will be helpful in reading the paper:

Induction heating - the generalization of heat within a metallic substance.

Dielectric heating - the generalization of heat within a nonmetallic substance.

Induction coil - a coil creating a magnetic field around the work by means of high-frequency alternating current.

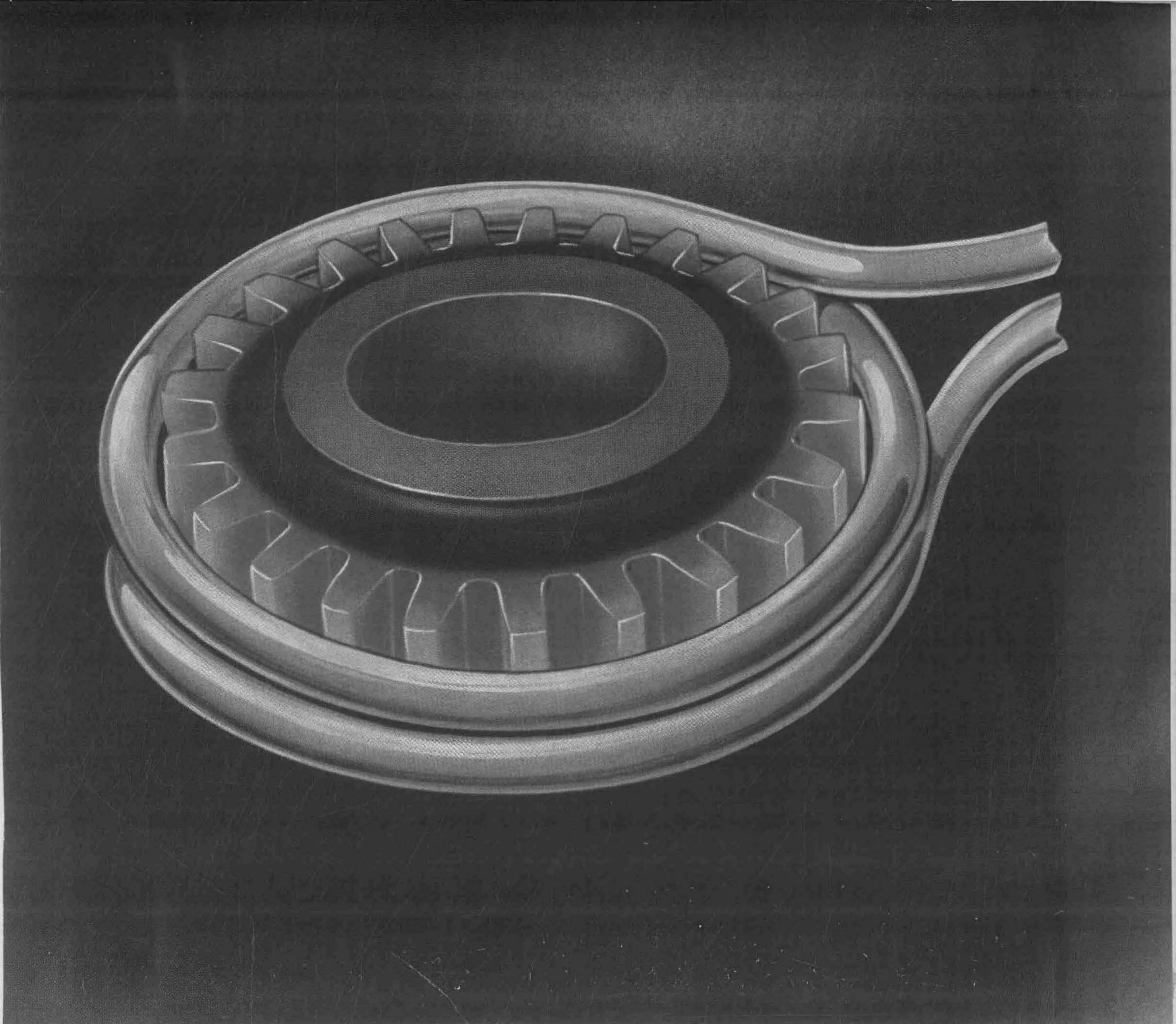
Work - the substance to be heated.

Frequency changing - to change the number of times per second at which an alternating current reverses direction.

= Dates? Abstract?

Chapter I

In many of the processes of modern day industry, the heating of materials has become an important procedure. Work, such as the heating of aluminum sheet, annealing, and progressive case hardening, requires long periods of time when the conventional methods of convection, conduction, and radiation are used. The loss of time and the consumption of man hours in the heating process has been, and is, a problem of great concern to industry. This important problem has largely been overcome in many of the phases of heating by the introduction of electronics. The use of electronics for the purpose of heating metallic sub-is called induction heating; in the non-metallic field it is called dielectric heating. These two forms of "heating without heat" have proved an enormous boon to industry. Not only do they answer the ever important production call for speed, but they save countless hours of heretofore wasted labor and provide large saving in essential floor space. Prehaps most important of all they have enabled industry to cut down on operational expenses.



GEAR HARDENING BY INDUCTION HEATING

How done?
Harden, a heat
An hardening
Guarding?

Chapter II

Section I

Induction Heating

Heat may be generated in any mass of metal or other conducting material which is subjected to the alternating magnetic field from a suitably designed coil, carrying current of proper magnitude and frequency. The coil is usually called an inductor coil and the mass of metal, or conducting material, is denoted as the work.

Heat is generated in the work because the magnetic field of the coil induces currents to flow around closed paths in the work, according to generally predictable patterns, depending upon the shape of the coil and the geometry of the work. These currents encounter resistance and power (which is a function of current and resistance) is expended in the form of heat.

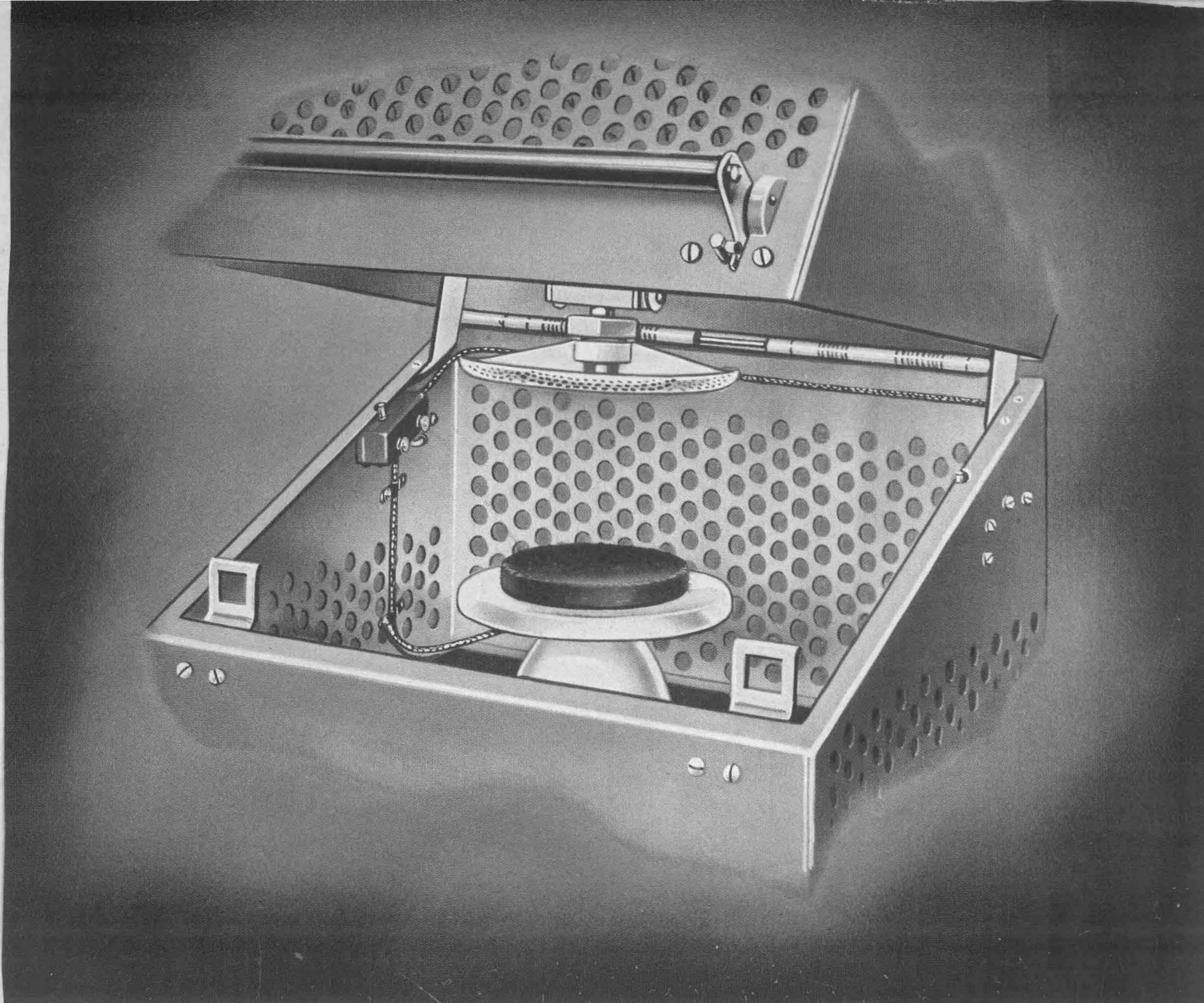
Whether heat is supplied by one of the conventional methods or by electric current, the amount of power which must be released to raise the temperature of a given mass through a given range in a given time can be calculated readily. In induction heating this is the power density and it is this power, neglecting radiation and conduction losses, which must be generated in the work.

When a conductor is carrying alternating current, the reactance is greater in the center of the conductor than it is at the surface. Currents always travel the path of lowest resistance and therefore the current density is greater at the surface than at any other point in the conductor. This is known as skin effect and it becomes very marked at high frequencies.

The skin effect is much greater in magnetic than in nonmagnetic materials. Therefore, most steels will heat more readily than such metals as copper, brass, and aluminum.

The inductor coil is the machine tool of the operation. It is always defined by the shape of the work and the heat pattern required. Its effectiveness varies inversely as its distance from the work, but it must be far enough away to prevent flashover to the work. It must be heavy enough to carry the required magnetizing current and generally must be water cooled because it has resistance, also, and would otherwise become overheated.

These are the basic elements of induction heating which, properly selected, enable industry to obtain the highest efficiency and best results. Induction heating offers new flexibility for both high and low production. Change-overs can be made quickly; small lots can be handled effectively. Brazing, soldering, annealing, melting ferrous and nonferrous metals, sintering powdered metals, heating for upsetting and forging...all these are handled with equal facility by induction heating.



PREHEATING PLASTIC PREFORMS BY DIELECTRIC HEATING

Means

Section II

Dielectric Heating

The most important characteristic of dielectric heating is its ability to create the heat uniformly within the material itself.

This significant feature makes dielectric heating an important tool in the fabrication of practically all non-conducting materials formed or processed with heat.

The degree to which such substances will heat is, in reality, a measure of their insulating qualities. And because there are few really good insulating substances at high frequencies, a great variety of non-conducting materials can be heated with a considerable degree of success.

If a non-conducting mass, generally referred to as the work, is placed between two electrodes and a source of alternating electric potential connected to the electrodes, the work and electrodes will behave like a capacitor and an alternating electric field will be set up between the two electrodes.

This alternating field, passing uniformly through the work, displaces or stresses the molecules of the material, first in one direction and then the other, as the polarity of the field is reversed. Friction occurs due to this molecular motion in the work and generates heat uniformly throughout the mass. Such molecular friction and the resulting heat generation is proportional to the field re-

Relation to previous chapters?

Chapter III

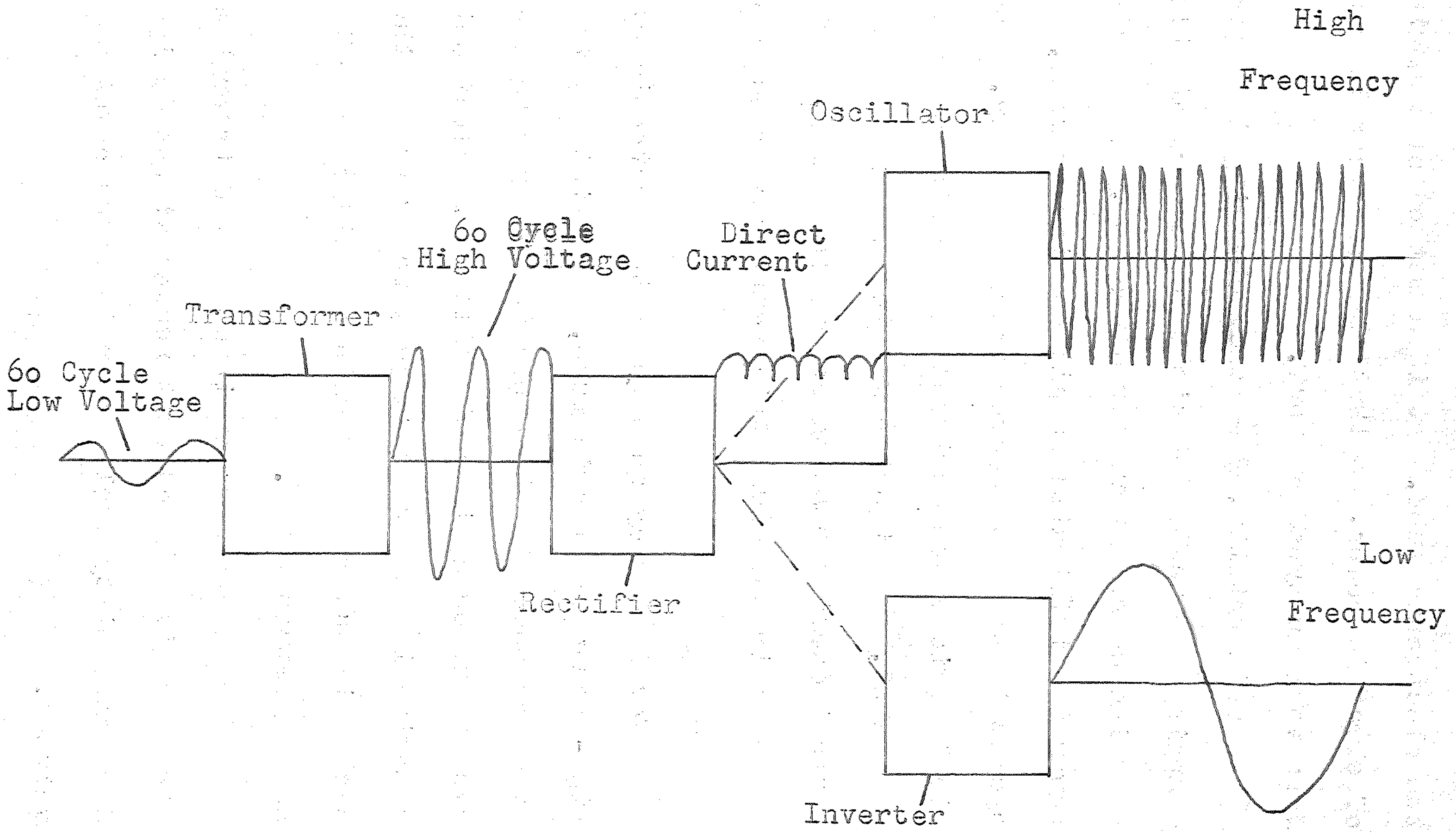
Electronic Frequency Changing

Frequency changing is one of the fundamental usea of the electronic tube. It is a method of changing the form of electric power, so that the power can be used to perform various types of work.

Fundamentally, frequency changing is a process for changing the number of times per second at which an alternating current reverses direction. Commercial electric power is distributed as alternating current, and sixty cycles is the most common power frequency. Most electrical devices are designed to operate on a current of sixty cycles, but high frequencies are needed for the electronic induction heating of metals. Also, high frequencies are used in the dielectric heating of nonconducting subtances

For frequency changing with electronic equipment the high-vacuum electronic tube, the pliotron, is used. It is used for power in the upper frequency ranges - above 10,000 cycles and on up into the millions. Electronic frequency changing in the lower ranges, below two or three thousand cycles is accomplished with the aid of gas-filled ignitron and thyratron tubes.

The electric power is converted through a series of steps to give the current needed at the desired frequency. Step one: Sixty cycle power is transformed to the required voltage.



High Frequency
Oscillator
60 Cycle High Voltage
Direct Current
Transformer
60 Cycle Low Voltage
Rectifier
Low Frequency
Inverter

Step two: The alternating current is rectified to direct current. The high-voltage alternating current is rectified by the one-way valve action of electronic tubes, giving a direct current. This direct current is the source from which a new alternating current at any frequency can be obtained.

Step three: The direct current is converted to the desired frequency. To obtain high frequency, the direct current is used to power an oscillator. To obtain low frequency, the direct current is used to power an inverter.

Step four: The alternating current output of the oscillator is then used to power the inductor coil in induction heating; the capacitor is used to do the work in dielectric heating.

Shown on the opposite page is a diagram of these four steps just explained.

Chapter IV

Section I

The Advantages of Induction Heating

The use of induction heating in industry contributes many important advantages. The heat input is controlled instantaneously; it is ideal for continuous processes - requires no physical contact between moving work and electrical circuits.

Induction heating eliminates time lost waiting for equipment to cool or reach proper temperature when servicing or making adjustments. Heat may be localized on internal or external surfaces for specific applications. It is unusally adaptable for high-speed production work...eliminates time and cost of transporting materials to and from heat-treating departments.

Induction heating can heat surfaces without affecting internal structure, where sufficient depth of material exists. Finally, accurate heat control simplifies repetitive heating and assures product uniformity.

Section II

The Advantages of Dielectric Heating

Dielectric heating contributes three specific advantages. Heat is evenly developed throughout the thickness of the product irrespective of its thermal conductivity. Heating is faster, particularly with thick masses, because it is unnecessary to wait for heat to penetrate from the outside surface to the center core.

With dielectric heating an improved product is obtained, not overheated at its surface with its core or interior under-cured.

Section III

Due to the manifold advantages of induction and dielectric heating it has found to be that they are an essential part in industry. These two forms of heating are comparatively new, but they are in wide use in the industries of gear hardening, brazing, tin reflowing, soldering, and annealing. In the textile industry, for curing plastic and wood laminates, plastic molding, rubber curing, and bonding, this form of heating has cut down tremendously on time and labor. The future of induction and dielectric heating is constantly being expanded by the numerous new applications to which they can be applied.

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