

IEEE Standard, Test Code, and Recommended Practice for Induction and Dielectric Heating Equipment

IEEE Std 54-1955

IEEE STANDARD
ARCHIVES
DO NOT REMOVE

Documents

Document Sharing Hub



Published by The Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street, New York, New York 10017

Authorized licensed use limited to: Tsinghua University. Downloaded on February 25, 2026 at 17:48:43 UTC from IEEE Xplore. Restrictions apply.

IEEE Standard, Test Code, and Recommended Practice for Induction and Dielectric Heating Equipment

© Copyright 1955 by

The Institute of Electrical and Electronics Engineers, Inc

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

CONTENTS

I. INTRODUCTION	5
II. STANDARDS	7
A. Scope	7
B. Definitions	7
C. Service Conditions	11
D. Rating of Oscillators, Converters, and Power Supplies ...	12
E. Temperature Rise and Dielectric Tests	12
F. Nameplates	12
G. Equipment	13
H. Auxiliaries	13
III. TEST CODE	14
A. Scope	14
B. Tests	14
IV. GUIDE FOR INSTALLATION, OPERATION and MAINTENANCE	19
A. Introduction	19
B. Rotary Equipment	19
C. Spark Gap Equipment	20
D. Vacuum Tube Equipment	21
E. Installation — General	23
APPENDIX	23
Applicable American Standards	23

ACKNOWLEDGEMENT

The personnel of the Induction and Dielectric Heating Subcommittee of the AIEE Committee on Electric Heating, which prepared this publication, was as follows :

W. C. Rudd, Chairman

R. M. Baker	T. P. Kinn
G. P. Bosomworth	E. Mittelman
E. W. Chapin	W. Paulin
F. T. Chesnut	G. W. Scott, Jr.
L. M. Duryee	J. T. Thwaites
J. E. Eiselein	R. S. Tucker
C. W. Frick	J. T. Vaughan
G. W. Klingaman	D. E. Watts
W. H. Hickok	O. Weitmann
R. J. Hunn	

IEEE Standard, Test Code, and Recommended Practice for Induction and Dielectric Heating Equipment

I — INTRODUCTION

Equipment — General

High-frequency heating equipments divide into two main types: (1) those used for dielectric heating, and (2) those used for induction heating. The induction heating equipments again divide into seven types: (1) commercial power line; (2) rotary generator; (3) mercury-arc converter; (4) gaseous-tube converter; (5) mercury-hydrogen spark-gap converter; (6) quenched spark-gap converter; (7) vacuum-tube generator.

Dielectric heating equipments in general use a vacuum tube oscillator as a source of radio-frequency power ranging in frequency from 2 megacycles to hundreds of megacycles. At frequencies above about 200 megacycles, the power is generated by devices other than a conventional vacuum tube, such as a magnetron, Klystron or other microwave device. A dielectric heating generator is normally a high-voltage generator, and application requires high-voltage radio-frequency matching techniques. An induction heating generator is essentially a high-current device operating into very low impedance circuits and sometimes requires transformation in the load circuit to provide the desired heating effect.

Use of High-Frequency Equipment

The wide variety of uses to which high-frequency heating is applied usually makes each installation a distinct type, utilizing a generator and a variety of auxiliary apparatus. Except in the case of rotating generators, the generator itself contains sufficient control apparatus and cooling systems to allow its operation under normal conditions. Where power above approximately 50 kilowatts is required, the generators may require auxiliary switch-gear and separate cooling systems.

In addition to the auxiliaries necessary to operate the generator, most installations require electric elements such as transmission lines, transformers, matching networks, controls, quench systems, special heating or cooling systems, etc., as additional auxiliary equipment.

Selection of Suitable Generating Equipment

A radio-frequency or rotating generator is rated in power output at its terminals. This power is seldom realized in the material to be heated when transformation or matching equipment is necessary, to match the load circuit to the generator. The electrical characteristics of the load and the individual generator characteristics dictate the auxiliary matching equipment required and the amount of power which will actually be transferred to

the load. All high-frequency heating loads are, in general, low power factor electric circuits, and the lower the power factor the more auxiliary matching or transformation equipment is needed, with a resultant lower transformation efficiency. This fact must be kept in mind when selecting a suitable generator for an application.

In dielectric heating applications, the selection of a suitable frequency is also essential. Here again, the power factor of the load controls the selection. In general, the lower the power factor of the load, the higher the frequency required to provide ease of generator matching. Load size also becomes a contributing factor in selection of frequency. The larger the physical size and, therefore, the larger the electrical capacitance of the load, the lower the frequency should be, to avoid non-uniform heating. Frequency selection, therefore, becomes a compromise between size and power factor characteristics of the load.

In the case of conveyORIZED dielectric heating applications where the load is passed between electrodes in a continuous manner, the selection of electrode size and therefore frequency becomes less critical. Size of the electrode in any case is limited by the ability to tune or adjust the overall electric load circuit to the frequency being used.

All of these factors are extremely flexible, and final selection of the generator, auxiliary equipment, and production rate must be made by competent personnel. For this reason, it is recommended that the manufacturer be consulted and provided with not only production requirements, but also electrical characteristics of the material to be heated in the case of dielectric heating. His engineers can then give proper advice on the suitability of a particular equipment.

Types of Heaters

A. Induction Heaters.—Although the field of application is extremely wide, nearly all induction heating devices can be classed in two main divisions; namely, those of the core type and those of the coreless type.

1. Core Type Induction Heaters.—Core type induction heaters or furnaces include all heaters in which the charge is heated by induction and a transformer iron core threads the charge. There are many other induction heaters in which cores are used as flux guides or shields but which, because the cores do not actually link the charge, are classed generally with those of the coreless type. The classification is not always easy to make.

Representative core type induction heaters include the following:

- a. Horizontal ring induction furnace
- b. Submerged resistor induction furnace
- c. Induction ring heater

2. **Coreless Type Induction Heaters.**—The coreless induction heater or furnace is an air-cored transformer whose primary is connected to an alternating-current source and whose secondary is an electrically conducting charge. No transformer iron threads the charge to be heated although such cores are sometimes used or useful for guiding the electromagnetic flux in prescribed paths about the charge.

The primary or work coil may surround the charge or be in any inductive relation with it.

Coreless induction heaters or furnaces operate at almost any frequency, but as a general rule the lower frequencies are more useful for low temperature or bulky loads and the higher frequencies are more useful for the higher temperature or less bulky loads.

Among the varieties of coreless induction heaters and furnaces are the following:

- a. Low-frequency induction heaters or furnaces
- b. High-frequency induction heaters or furnaces
- c. Dual-frequency induction heaters or furnaces
- d. Hysteresis heating devices
- e. Autoregulation induction heating devices
- f. Motor field induction furnaces
- g. Domestic induction heating devices
- h. Induction-conduction heaters
- i. Induction sheet or strip heaters

- B. **Dielectric Heaters.**—Dielectric heaters can be classified according to the location of the electric field with respect to the dielectric material to be heated. The two main classes are normal (through) dielectric heating applications and stray field dielectric heating applications.

1. **Normal (Through) Dielectric Heating Applications.**—The metallic electrodes are arranged on opposite sides of the material so that the electric field is established through it. The electrodes may be classified as plate electrodes, roller electrodes, or concentric electrodes.

- a. **Plate Electrodes.**—Plate electrodes may have plane surfaces or surfaces of any desired shape to meet a particular condition, and the spacing between them may be uniform or varied.
- b. **Roller Electrodes.**—These electrodes are rollers separated by the material which moves between them.
- c. **Concentric Electrodes.**—Concentric electrodes consist of an enclosed and a surround-

ing electrode, with the material placed between the two.

2. **Stray Field Dielectric Heating Applications.**—The metallic electrodes are arranged on the same side so that the stray field penetrates the material.

The depth of heating can be controlled by the spacing between electrodes. Stray field dielectric heating utilizes finger electrodes or cuff electrodes.

- a. **Finger Electrodes.**—Finger electrodes consist of rods or bars alternately connected in such a manner that an electric field is established between them.
- b. **Cuff Electrodes.**—Cuff electrodes are generally similar to finger electrodes with the exception that the bars or rods are continuous and form loops or cuffs around the material.

3. **Combination Normal and Stray Field Dielectric Heating Applications.**—These include systems in which the electrodes are so arranged that the electric field between opposing electrodes will pass both through and along the surface of the material.

- C. **Wave Heaters.**—Wave heaters are those in which heating is produced by energy absorption from a traveling electromagnetic wave.

Frequency Bands.—The scope of the definitions in this standard provides for coverage of all types of induction and dielectric heating devices encompassed within the frequency bands numbered and designated below.

Band No.

0	1	to but not including 10	cycles per second
1	10	to but not including 100	cycles per second
2	100	to but not including 1,000	cycles per second
3	1	to but not including 10	kilocycles per second
4*	10	to but not including 100	kilocycles per second
5*	100	to but not including 1,000	kilocycles per second
6*	1	to but not including 10	megacycles per second
7*	10	to but not including 100	megacycles per second
8*	100	to but not including 1,000	megacycles per second
9*	1,000	to but not including 10,000	megacycles per second
10*	10,000	to but not including 100,000	megacycles per second

* Bands No. 4 and up may be called "radio frequency."

Power Sources.—Power sources most commonly employed for induction or dielectric heating are listed below, together with their most usual range of frequencies and accepted terminology.

Commercial Power Lines

25 to 60 cycles per second

Generator — Rotary Type

25 to 10,000 cycles per second and up

Converter — Pool-Cathode, Mercury-Arc Type

25 to 3,000 cycles per second

Converter — Gaseous Tube Type

25 to 3,000 cycles per second and up

Converter — Mercury-Hydrogen Spark-Gap Type
10 to 80 kilocycles per second
Converter — Quenched Spark-Gap Type
125 to 500 kilocycles per second and up
Generator — Vacuum Tube Type
100 kilocycles per second and up

II — STANDARDS

A—SCOPE

These standards apply to all types of induction and dielectric heating equipment, including those listed below:

Commercial power line
Rotary generator
Mercury-arc converter
Gaseous tube converter
Mercury-hydrogen spark-gap converter
Quenched spark-gap converter
Vacuum tube generator

Cross References
to Allied Subject
Definition Number

B—DEFINITIONS

1. **Applicators or Electrodes** (Dielectric heating usage)—Applicators are appropriately shaped conducting surfaces between which is established an alternating electric field for the purpose of producing dielectric heating.
2. **Applicator Impedance, Loaded** 81
3. **Applicator Impedance, Unloaded** 133
4. **Autoregulation Induction Heater** — An autoregulation induction heater is an induction heater in which a desired control is effected by the change in the characteristics of a magnetic charge as it is heated at or near its Curie point. 20
5. **Cavity** 135, 136
6. **Channel, Melting** 94
7. **Charge or Load** 76
8. **Coaxial Conductor**—A coaxial conductor is an electric conductor comprising outgoing and return current paths having a common axis, one of the paths completely surrounding the other throughout its length.
9. **Coil Q**—Coil Q is ratio of reactance to resistance measured at the operating frequency.
Note: The loaded-coil Q is that of a heater coil with the charge in position to be heated. Correspondingly, the unloaded-coil Q is that of a heater coil with the charge removed from the coil.
10. **Coil Shape Factor**—Coil shape factor is a correction factor for the calculation of the inductance of a coil based on its diameter and length.

Cross References
to Allied Subject
Definition Number

11. **Colpitts Oscillator**—A Colpitts oscillator is an electron tube circuit in which the parallel-tuned tank circuit is connected between grid and plate, the capacitive portion of the tank circuit being comprised of two series elements, the connection between the two being at cathode potential with the feedback voltage obtained across the grid-cathode portion of the capacitor. 114
12. **Conductor, Coaxial** 8
13. **Contact or Switch, Load** 87
14. **Converter, Pool-Cathode Mercury-Arc** 106
15. **Converter, Quenched Spark-Gap** 112
16. **Converter, Mercury-Hydrogen Spark-Gap** 96
17. **Core Type Induction Heater or Furnace**
—A core type induction heater is a device in which a charge is heated by induction and a magnetic core links the inducing winding with the charge.
18. **Coreless Type Induction Heater or Furnace**—A coreless type induction heater is a device in which a charge is heated by induction and no magnetic core material links the charge.
Note: Magnetic material may be used elsewhere in the assembly for flux guiding purposes.
19. **Coupling** (Induction heating usage) — Coupling is the percentage of the total magnetic flux, produced by an inductor, which is effective in heating a load or charge.
20. **Curie Point** (Induction heating usage)— 21, 116
The Curie point is the temperature in a ferromagnetic material above which the material becomes substantially non-magnetic.
Note: The Curie point may be reduced slightly in some cases of high-density induction heating by stresses resulting from high temperature gradients.
21. **Decalescent Point**—The decalescent point is the temperature at which there is a sudden absorption of heat when metals are raised in temperature. 20, 116
22. **Depth of Heating** (Dielectric heating usage)—The depth of heating is the depth below the surface of a material in which effective dielectric heating can be confined when the applicator electrodes are applied adjacent to one surface only.
23. **Depth of Current Penetration** (Induction heating usage)—The depth of current penetration is the thickness of a layer extending inward from the surface of a conductor which has the same resistance to direct