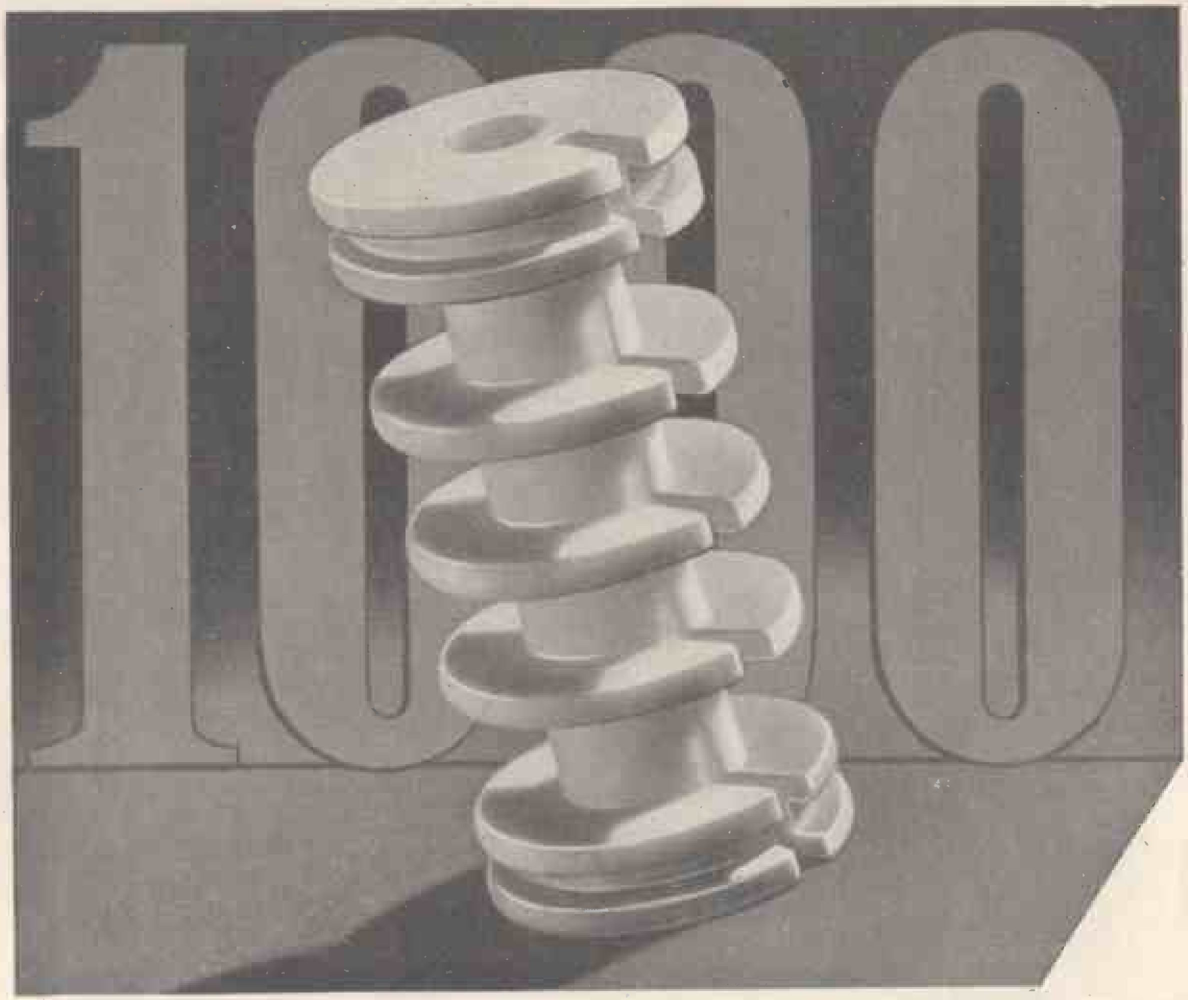
Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

H.F. HEATING NUMBER

2/- AUG., 1945


1000

ELECTRONICS

made it possible!

One of the OSRAM VALVES specially developed for Radar—an ACT 20 which will find many peace-time applications.

Hostiles, bearing 194, height 10,000 — back went the warning and fighters raced to intercept. From many miles away Radar plotted the enemy's exact position, and brought the defences hurtling into action.

The science of electronics made it possible, for at the heart of every Radar installation lies the valve.

OSRAM VALVES have been in the forefront of electronic development during the war, and will bring to the pursuits of peace many well tried electronic devices to speed, smooth and make safer our way of life.

Osram
PHOTO CELLS

G.E.C.
CATHODE RAY TUBES

Osram Valves

Advt. of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.


TYPE APPROVED

U.I.C.

CERAMIC
High Voltage CAPACITORS

Outstanding characteristics of U.I.C. Pot and Plate Capacitors are the high break-down strength, low loss factor, and small dimensions. *Working Voltage:* 10 KV D.C. only or 7.5 KV D.C. Peak + A.C. *Working Load R.F.:* Up to 25 KVA according to type. *Max. Current:* Up to 14 AMP. according to type. *Range of Capacitance:* 5 pF to 1200 pF. Tested to Specification K110. Full details on request.

UNITED INSULATOR CO. LTD. 12-22 LAYSTALL STREET, LONDON, E.C.1
Tel.: TERminus 7383 (5 lines) Grams.: Calanel, Smith, London

THE PIONEERS OF LOW LOSS CERAMICS

SOLON Industrial Type Electric Soldering Irons rated at 65 watts are now available for use for low voltages. Two models, one fitted with round pencil bit as illustrated, the other with oval tapered bit, they will do the same work as the well-known SOLONS of 65 watt rating for normal voltages.

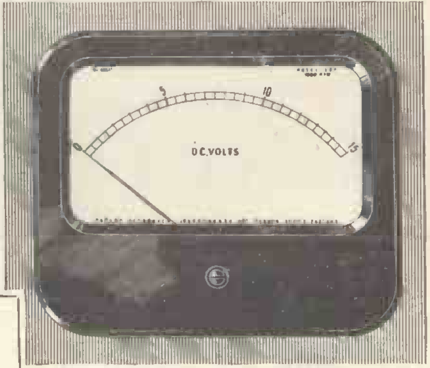
Design incorporates the many special SOLON features, including fitting of heating element **inside the bit.** Both models can be supplied fitted with elements for 12 volts or 24 volts as required. Complete with 6 feet of HENLEY twin core flexible.

SOLON
Electric
SOLDERING IRON FOR INDUSTRIAL USE

Write for details of the complete SOLON range for low and normal voltages.

W. T. HENLEY'S TELEGRAGH WORKS CO., LTD.
(Eng. Dept.) MILTON COURT, WESTCOTT, DORKING, SURREY

A TAYLOR FAMILY



MODEL 500
5" scale.
Size $6\frac{1}{4}" \times 5\frac{1}{4}"$
MODEL 400
4" scale
Size $4\frac{7}{8}" \times 4\frac{1}{8}"$
MODEL 350
$3\frac{1}{2}"$ instrument type.
Flush or Projecting.

These moving coil instruments are very soundly constructed, and are accurate and dependable in use. A very large number of ranges are available in moving coil, Rectifier and Thermocouple type instruments.
Model 400 and 500 instruments are also available with illuminated dials.
All models are supplied in black moulded insulated cases, and Alnico magnets and stainless iron polepieces and cores are used.

We also manufacture several other sizes of moving coil instruments with scales of 2" and up.

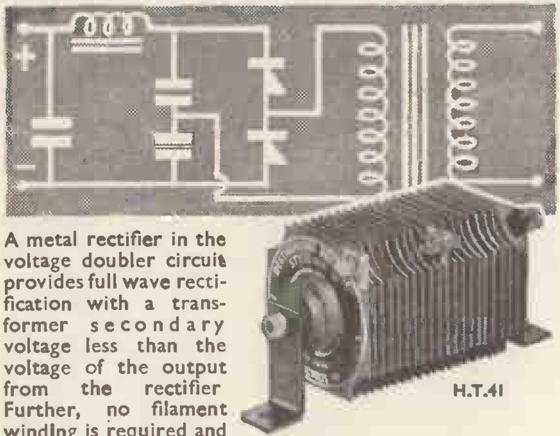
IMMEDIATE DELIVERY.
For some time past we have been carrying a small varied stock of most ranges of moving coil instruments. We are able to give immediate delivery for urgent orders.

Send your enquiries to

Taylor
electrical instruments ltd.

TAYLOR ELECTRICAL INSTRUMENTS, LTD.,
419—424 Montrose Avenue, Slough, Bucks.
Telephones: Slough 21381 (4 lines). 'Grams: "Taylins, Slough."

LONG LIFE, HIGH EFFICIENCY AND
A SIMPLE CIRCUIT



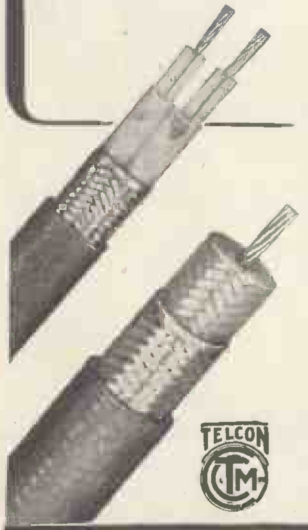
A metal rectifier in the voltage doubler circuit provides full wave rectification with a transformer secondary voltage less than the voltage of the output from the rectifier Further, no filament winding is required and the transformer is simpler and less costly.

WESTINGHOUSE
METAL RECTIFIERS

WESTINGHOUSE BRAKE & SIGNAL CO. LTD.
Pew Hill House, Chippenham, Wilts.

★ SUPREME FOR RADIO COMMUNICATIONS

TELCON CABLES
with
TELCOTHENE
REGD.
INSULATION



This new material produced by TELCON is the latest development in low loss thermoplastic Insulants. A complete range of "TELCOTHENE" insulated cables is now available for use in the Audio, Radio and Ultra High Frequency fields.

Send for H.F. brochure.

TELCON Designed H.F. Cables are the Basis of World Standards.

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD.
Founded 1864
Head Office: 22 OLD BROAD ST., LONDON, E.C.2. Tel: LONdon Wall 3141
Enquiries to TELCON WORKS, GREENWICH, S.E.10. Tel: Greenwich 1040

Electronic Engineering

AUGUST, 1945
Volume XVII. No. 210.

CONTENTS

CONDITIONS OF SALE—This periodical is sold subject to the following conditions, namely, that it shall not without the written consent of the publishers first given, be lent, re-sold, hired out or otherwise disposed of by way of Trade except at the full retail price of 2/- and that it shall not be lent, re-sold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade, or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

URGENT! SAID THE G.P.O

So Mazda Valves helped to break a bottleneck in submarine cable traffic

Beneath the Irish Sea lies a telephone cable that now carries double its peak load.

The British Post Office answered the urgent demand for greater inter-country communications by introducing a submerged Repeater into the cable which increased its simultaneous telephone circuit from 24 to 48.

Weighing nearly a ton, this repeater must give absolutely reliable service under these exacting conditions year in and year out, because to lift it from the sea-bed is a major and expensive operation.

Standard Mazda SP.41 valves were chosen for this amplifier following ageing tests on numerous different types. Checked again after 11,000 hours continuous operation, the valves were found as serviceable as ever.

Mazda are proud of their contribution to this great development in submarine cable facilities — proud of the proved reliability of their standard valve. This is but one instance of the reliable service Mazda valves are giving in many spheres where technical discoveries are hastening the birth of a new age.

MAZDA valves

FOR INDUSTRIAL, MEDICAL, RADIO, SCIENTIFIC, TELEPHONIC AND DOMESTIC APPLICATIONS

THE EDISON SWAN ELECTRIC CO., LTD.,
155 CHARING CROSS RD., LONDON, W.C.2.

PROPRIETORS:
HULTON PRESS, LTD.

Electronic Engineering

EDITOR
G. PARR.

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 43-44, SHOE LANE, LONDON, E.C.4

TELEPHONE:
CENTRAL 7400

Monthly (published last day of preceding month) 2/- net. Subscription Rates: Post Paid to any part of the World—6 months, 13/-; 12 months, 26/-. Registered for Transmission by Canadian Magazine Post.

TELEGRAMS:
HULTONPRES, LUD
LONDON.

B.S. 1219

THE British Standards Institution has recently issued a Standard of particular interest to contributors to this and other technical journals: B.S. 1219, Printers' and Authors' Proof Corrections.

The symbols and recommendations are those approved by a representative Committee of members of the printing and publishing professions together with those of the authors' and journalists' associations.

The part of the Standard which will be found of value by newcomers to technical writing is that dealing with the preparation of copy for the printer. For example, it is recommended that mathematical expressions should be set out in a particular manner which experience has shown to be least troublesome to the compositor.

Incidentally, the subject of setting out mathematical expressions is dealt with very thoroughly in an excellent booklet, "The Preparation of Mathematical Papers," issued by the London Mathematical Society and published by Messrs. Hodgson & Son,* Newton Street, W.C.2.

The recommended method of setting out references in a bibliography is worthy of note. Such a reference should give, in order: Author's name; full title of article; recognised abridged title of journal in which the paper appears†; volume number, date of publication, and page numbers.

An example is quoted in the Standard:

LITTLEWOOD, D. E. On the number of terms in a simple algebraic form. *Proc. Camb. Phil. Soc.* 38 (1942), 304-6.

References to books should be set out:

ROGET, P. M. *Thesaurus of English words and phrases.* Longmans (London, 1852.)

This method of reference differs from that in use in some scientific journals, notably the *Proc. Roy. Soc.*, and the medical journals, but it seems to be generally in use with minor modifications, and will be adopted as standard by this journal.

The prospective author need not be alarmed at the thought of having to memorise a list of cabbalistic signs in order to make his wishes known to the publisher of his article. He will find, on reading through the list, that there are perhaps a dozen signs with which he should be familiar, but if in doubt on one of the lesser known markings it is best to use commonsense and explain what is required in a marginal note.

The printer's compositor is a highly skilled craftsman, but he is not a diviner, and he appreciates the help which is given him in the form of clear instructions.

Copies of B.S. 1219 can be obtained from the British Standards Institution, 28, Victoria Street, S.W.1, price 2s., post free.

---

* Obtainable from the publishers, price 1/2 post free.

† The recognised abridged titles are, in the main, those in use by Science Abstracts.

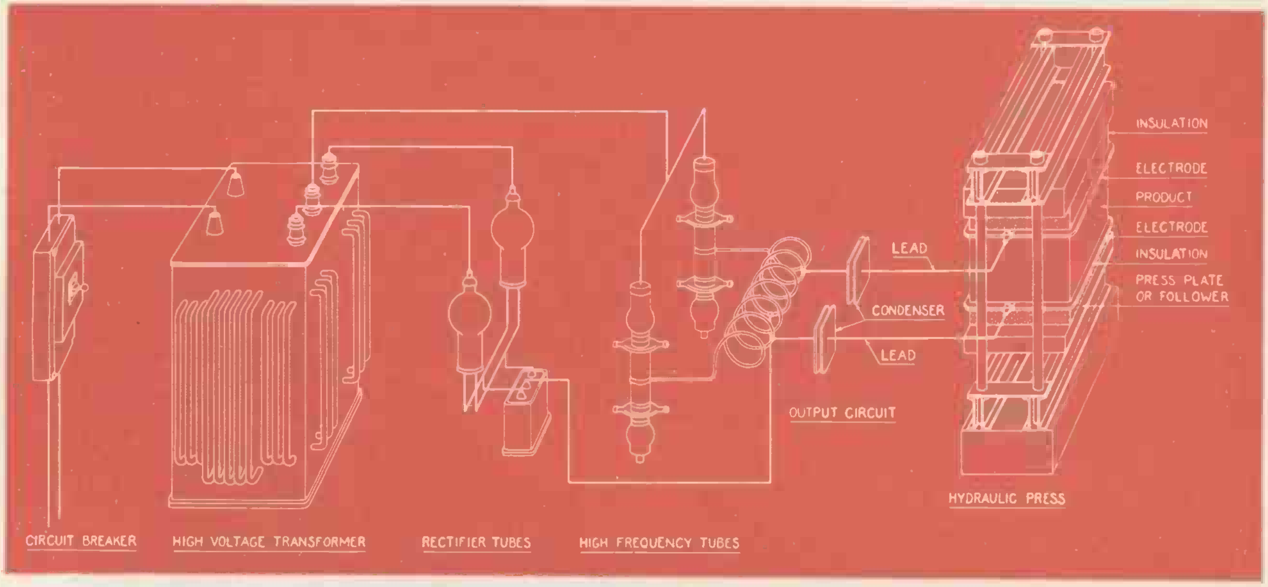


Fig. 4. **"Thermex" H.F. equipment connected to hydraulic press.**
(The Girdler Corp., Louisville, Kentucky.)

High Frequency Dielectric Heating

By A. E. L. JERVIS

DURING the past three years the technical Press on both sides of the Atlantic has given considerable attention to the subject of high frequency heating. The applications are manifold and ingenious and in this review an attempt will be made to cover some of the published applications, although some of them are in their infancy and all of them may not survive in a hard commercial world.

As opposed to the standard method of heating a material from the outside (in which case time has to be allowed for the heat to reach the interior by conduction) the heating effect when using high frequency is produced internally because the material itself is used as a conductor and provided it is homogeneous it will, theoretically, heat up uniformly and simultaneously throughout. (In practice, the temperature may not be quite uniform throughout as the electrodes may absorb some of the heat generated.) It has been found that the greater the frequency of the alternating current employed the greater is the molecular friction and consequent heating up of the material under treatment. Fig. 1 is intended to represent internal and external heating.

The most obvious advantage possessed by H.F. heating is its time-saving factor. At outstanding example is quoted where 6 in. thick blocks of laminated wood have to be heated for nine hours before the inner glue lines are melted and polymerised when using the platen method. In the case where high frequency heating has been employed, the time can be reduced from hours to minutes (*see* Figs. 2 and 3).

To illustrate the diversity of high frequency heating applications the following are quoted:—

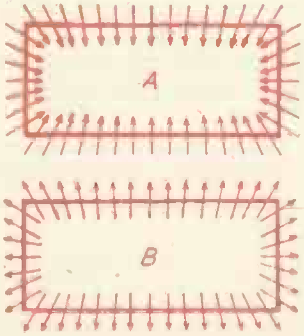


Fig. 1. Diagrammatic illustration of heat flow. (A) Oven heating. (B) High frequency heating.
—After J. P. Taylor.

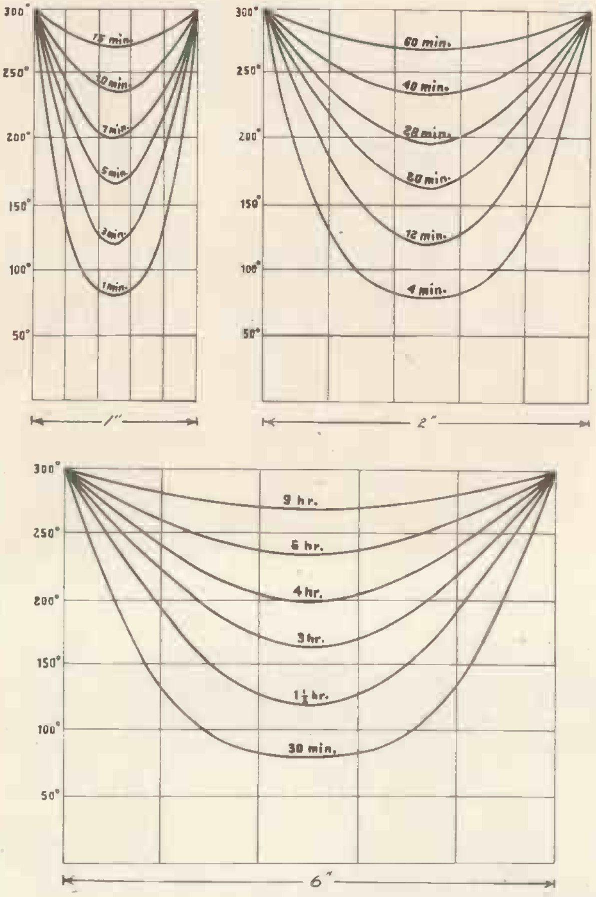
Medical diathermic treatment.
The dehydration and sterilisation of food.
Melting and setting of glue lines.
Melting and in some cases the curing of mouldings.
Seam welding of thermoplastics.

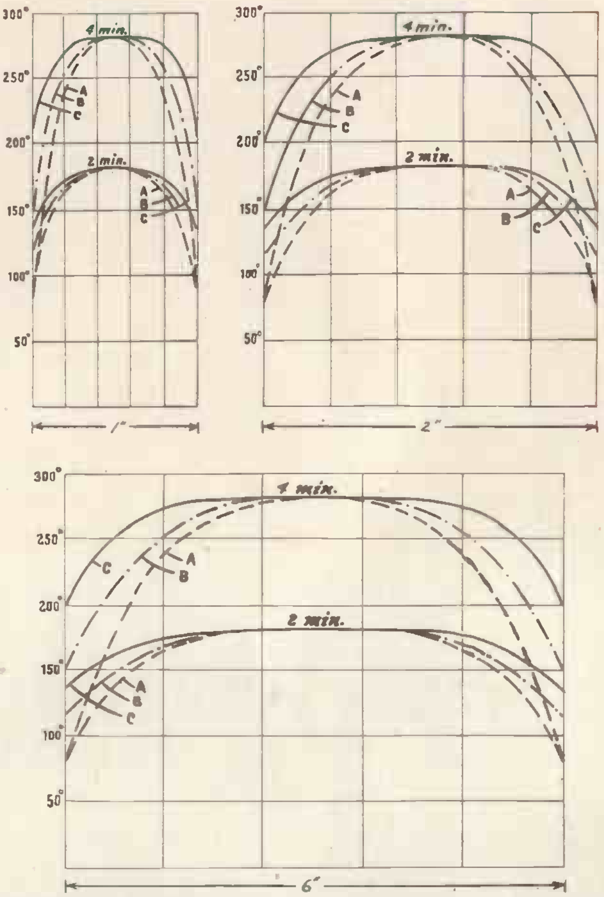
The subject of High Frequency Therapy was discussed some time ago in this journal.* One of the earliest applications relates to medical diathermic treatment of the human body and is attributed to Arsène d'Arsonval and the resulting work founded on his experiment at the Collège de France in Paris in 1890. A century before this, Galvani had, of course, carried out his electrical experiments utilising the lower limbs of a frog.

Outside the medical profession the Thermal Engineering Corporation of Richmond, Va. (a concern interested in the processing of tobacco), during 1936 was searching for a method of evaporating moisture from tobacco without removing it from the hogsheads in which it was stored and shipped. The solution of the problem was to make the tobacco the dielectric in a condenser subjected to

---

* "High Frequency Therapy," W. D. Oliphant, *Electronic Engineering*, Sept., 1943, to April, 1944, inclusive.





Time/Temperature distribution curves for various thicknesses of spruce.

Fig. 2.
Heating by steam platens.

Fig. 3.
High frequency heating.

A—wood against cold plates.
B—wood against thin electrodes.
C—thin insulator between wood and platens.

—*After J. P. Taylor.*

a rapidly alternating potential and to take advantage of the usually undesired condenser losses. The early results were so successful that the method attracted attention as a means of killing insect infestation in grains and cereals and for the setting of glues and resin cements in the manufacture of plywood.*

Equipment Already Available

It is interesting to note the sizes of high frequency heating equipment now available. A typical range is as follows: 3 kW, 5 kW, 7½ kW, 8 kW, 10 kW, 12½ kW, 15 kW, 18 kW, 25 kW, 40 kW, 60 kW, 80 kW, 100 kW, 250 kW, with a selection of frequencies up to 300 Mc/s.

One of the largest applications of H.F. heating is in the laminated wood field.* Sets as large as 600 kW are quoted as in use in the U.S.A. for high frequency laminating, which is the term suggested by the author for this field of application in order to distinguish it from high frequency moulding (in which case much smaller sets are used, generally less than 100 kW and sometimes as small as 500 watts).

Principle

A typical circuit diagram of the apparatus required for generating the high frequency current is shown in Fig. 4. The material to be heated is placed between two metal plate electrodes connected to an oscillatory circuit containing a coil and condensers of suitable design.

There are many kinds of electrodes used in high frequency heating. For handling cylindrical moulding preforms, thin circular metal plates are used (Fig. 5) and for the preheating of wood blocks thin rectangular sheets. In some cases it is more convenient to deposit a metal coating on a low loss insulator such as "Mycalex."

It is possible in the case of laminated wood heating to place an electrode half-way down the material being handled, utilising the top and bottom plates of the press as earthed electrodes, thus simplifying some of the insulation problems associated with high frequency heating.

An arrangement of thin rectangular

---

* T. R. Olive, *Chem. & Met. Eng.*, April, 1943, p. 102.

* There is also available another method of heating the glue lines of laminated wood, utilising low-voltage D.C. or 50 c/s. A.C.

electrodes backed by low-loss insulation is shown in Fig. 6, which depicts an experimental spring-loaded jig* used for laboratory experiments for heating glue lines in laminated wood, and this is the arrangement visualised in the calculations which follow, although, as already explained, not all high frequency heating set-ups employ two electrodes in this manner. The two metal plates with the intervening dielectric form a condenser in which losses occur. Fig. 6a represents an air condenser in which current I_c leads voltage E by 90°. Fig. 6b shows the same condenser with a dielectric of laminated wood. The loss which occurs in the condenser is represented by an equivalent parallel resistance R_p. Current I_r is in phase with voltage E and resultant current I leads the voltage by angle θ. The alternating field causes molecular friction which manifests itself in the form of heat. The amount of heat produced depends, of course, upon the actual material. The case of laminated wood has been examined extensively by Mr. J. P. Taylor, whose paper before the A.S.M.E. contained heating curves (Figs. 7a and 7b) connecting watts per cubic inch and time in minutes for a given temperature rise.

Formulae

The formula used in calculating the values is:

Power in watts.

$$W = \frac{0.637 \times p \times c \times t \times V}{T} \quad \dots (1)$$

where:

p = specific heat in calories per gram per degree C.

c = density in grams per cubic centimetre.

t = change in temperature per degree Fahr.

V = volume in cubic inches.

T = time in minutes.

The formulae involved in the electrical calculations are as follow:

Power factor.

$$\cos\theta = I_r/I \quad \dots\dots (2)$$

Since $\cos\theta$ is small, the expression can be written:

$$\cos\theta = I_r/I_c \quad \dots\dots (2a)$$

Current.

$$I_r = I_c \cos\theta \quad \dots\dots (3)$$

or

$$I_r^2 = W/R_p \quad \dots\dots (3a)$$

Power loss in watts.

$$W = E \times I_c \cos\theta \quad \dots\dots (4)$$

or

$$W = E^2 \times 2\pi \times f \times C \times \cos\theta \quad (4a)$$

Capacitance.

$$C = 8.85 \times 10^{-14} \times \frac{K \times A}{d} \quad (5)$$

Capacitive reactance

$$X_c = \frac{1}{2 \times \pi \times C \times f} \quad \dots\dots (6)$$

Equivalent resistance.

$$R_p = \frac{X_c}{\cos\theta} \quad \dots\dots (7)$$

The symbols used above represent the following:

$\cos\theta$ = Power factor.

K = Dielectric constant.

I = Resultant current in amps.

I_c = Capacity current in amps.

I_r = Current in equivalent parallel resistance in amps.

W = Power loss in watts.

E = Volts.

C = Capacity in farads.

R_p = Equivalent parallel resistance in ohms.

X_c = Capacitance in ohms.

f = Frequency in c/s.

A = Area of each electrode (sq. cm.)

d = Distance between electrodes (cm.)

Fig. 5. Moulded preform between the electrodes in a H.F. cabinet. *(By courtesy of Modern Plastics.)*

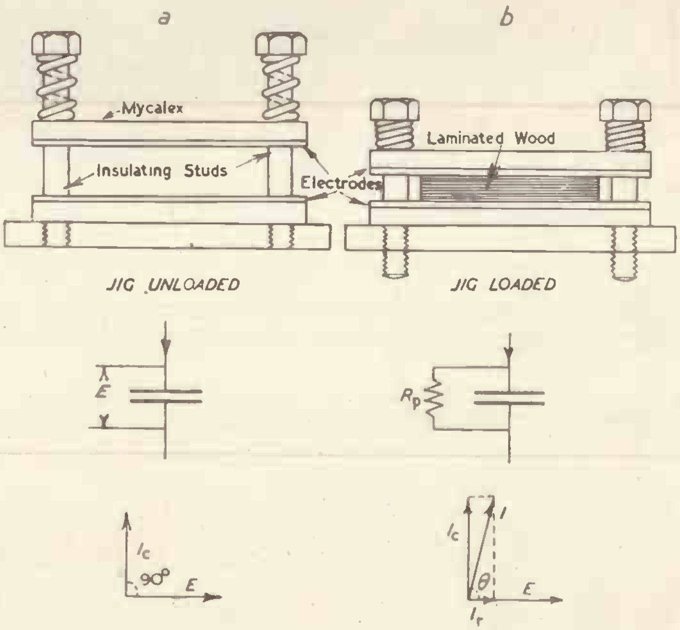
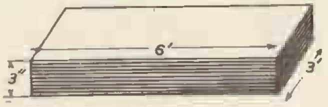


Fig. 6. Sketch of experimental spring-loaded jig and vector diagrams of the equivalent circuit when loaded and unloaded.

---

* The late Captain Jarrard produced on a jig of this type some of the earliest plastic samples.

Typical Calculations for Laminated Wood Boards

Dimensions of Block :			
Volume (V) (cubic inches)	$72 \times 36 \times 1$	$72 \times 36 \times 3$	…………… (8)
Watts (W)*	$72 \times 36 \times 1 \times 5$ $= 12{,}960$	$72 \times 36 \times 3 \times 3$ $= 23{,}328$	…………… (9)
Ratio $\left(\frac{KA}{d}\right)$ (A in sq. cm., d in cm.)	$\frac{5 \times 36 \times 72 \times 2.54 \times 2.54}{1 \times 2.54}$ $= 12{,}960 \times 2.54$ $= 3.3 \times 10^4$	$\frac{5 \times 36 \times 72 \times 2.54 \times 2.54}{3 \times 2.54}$ $= 4{,}320 \times 2.54$ $= 1.1 \times 10^4$	…………… (10)
Capacitance (C) $\frac{8.85 \times 10^{-14} KA}{d}$	$8.85 \times 10^{-14} \times 3.3 \times 10^4$ $= 8.85 \times 3.3 \times 10^{-10}$ $= 29.2 \times 10^{-10}$ $C = 3 \times 10^{-9}$ farads approx.	$8.85 \times 10^{-14} \times 1.1 \times 10^4$ $= 8.85 \times 1.1 \times 10^{-10}$ $= 9.7 \times 10^{-10}$ $C = 1 \times 10^{-9}$ farads approx.	…………… (11)
Capacitive reactance (X_c) $\left\{ \frac{1}{2\pi C f} \quad \frac{1}{2\pi f} = \frac{1 \times 7}{2 \times 22 \times 30 \times 10^6} = 0.53 \times 10^{-8} \right\}$	$\frac{0.53 \times 10^{-8}}{3 \times 10^{-9}}$ $= \frac{0.53 \times 10}{3}$ $= 1.77$ ohms approx.	$\frac{0.53 \times 10^{-8}}{1 \times 10^{-9}}$ $= 0.53 \times 10$ $= 5.3$ ohms approx.	…………… (12)
Equivalent resistance (R_p) $\left\{ R_p \frac{X_c}{\text{P.F.}} \right\}$	$\frac{1.77}{0.05}$ $= 35$ ohms	$\frac{5.3}{0.05}$ $= 106$ ohms	…………… (13)
Power loss (Watts)	12,960	23,328	…………… (14)
Current (*I*) $\left\{ I^2 = \frac{\text{Power}}{R_p} \right\}$	$I^2 = \frac{12{,}960}{35}$ $= 370$ $I = 19^a$ approx.	$I^2 = \frac{23{,}328}{106}$ $= 220$ $I = 15^a$ approx.	…………… (15)
Voltage (E) $I \times R_p$	$E = 19 \times 35$ $= 665$ volts	$E = 15 \times 106$ $= 1{,}590$ volts	…………… (16)

The following assumptions are made:

Temperature rise, 320° F.

Assumed heating time: 10 minutes for 1-in. board
20 minutes for 3-in. board

$p \times c$ value $= 0.3$

Power factor, 0.05

Dielectric constant, 5

Frequency, 30 Mc/s.

Watts required per cubic inch: 5 for 10 minutes (1-in. board)
3 for 20 minutes (3-in. board)

* The power given is output power used up in the wood. The actual power supplied to the press will have to be slightly higher to allow for losses due to conduction and radiation.

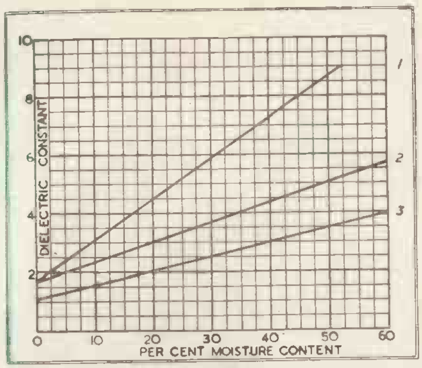


Fig. 8.

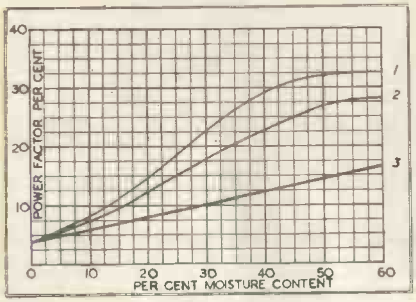
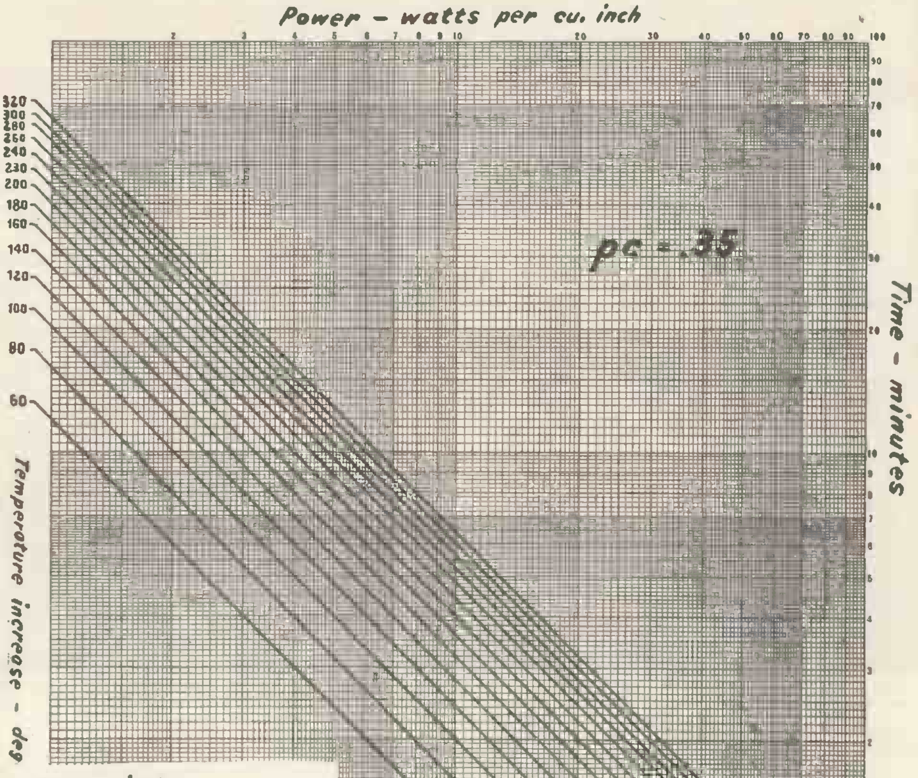
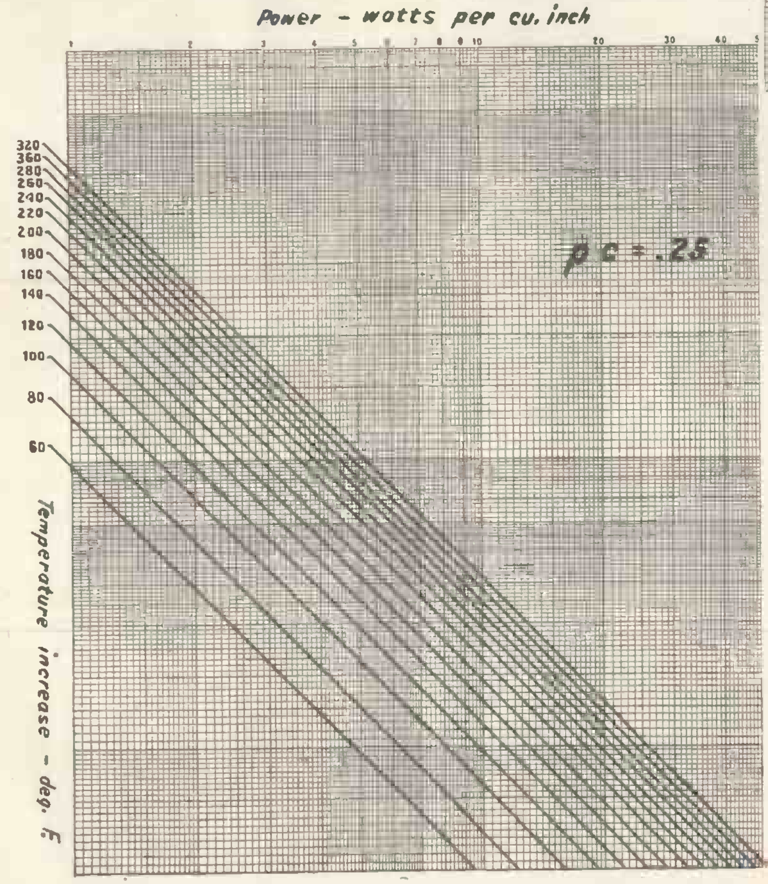


Fig. 9.





Typical curves of Temperature rise/Power Power factor/Moisture content Dielectric constant / Moisture content

—From J. P. Taylor's paper, "Heating Wood with R.F. Power."
Trans. A.S.M.E., April, 1943, p. 201.

Fig. 7a. Power in watts per cu. in./Time in minutes to raise the temperature of wood. p.c. value = 0.25.

Fig. 7b (top right). Power in watts per cu. in./Time in minutes to raise the temperature of wood. p.c. value = 0.35.

Fig. 8. Variation of dielectric constant with moisture content. (1) Maple, (2) Mahogany, (3) Spruce.

Fig. 9. Variation of power factor with moisture content. (1) Maple, (2) Mahogany, (3) Spruce.

A BIBLIOGRAPHY OF H.F. HEATING

TITLE	*AUTHOR*	*REFERENCE*
GENERAL		
Capacity Current Heating	L. J. C. Connell	*G.E.C. Journal*, February, 1944, p. 26
Principle Limitations of Dielectric Heating	C. J. Madsen	*Plastics*, May, 1945, p. 238
Possible Industrial Uses of H.F. Electrostatic Heating	J. P. Jordan	*Electrical News & Engineering*, November, 1942, p. 38
Induction and Dielectric Heating Types and Applications of H.F. Generation	C. A. Scarlott	*Electrical News & Engineering*, May 1, 1944, p. 55
Valve Generated H.F. Heating Equipment	L. J. C. Connell	*Engineering*, February, 1944, p. 50
H.F. Heating of Non-Metallic Materials	A. D. Little	*Engineer*, 1943, p. 134
Theory and Practice of Industrial Electronic Heating	J. P. Jordan	*General Electric Review*, 1943, p. 675
Electrostatic Heating	J. F. Driver	*Machinery Lloyd*, 1943, p. 37
H.F. Heating	D. W. Brown	*Plastics*, May, 1944, p. 218
R.F. Heating	G. H. Brown	*Chemical Age*, 1944, p. 364
Dielectric Heating—A Potential Method for the Chemical Industry	C. N. Hoyler	*Chemical Age*, 1943, p. 210
H.F. Heating of Non-Metallic Materials	T. R. Olive	*Chemical & Metallurgical Engineering*, April, 1943, p. 102
Principle Limitations of Dielectric Heating	C. J. Madsen	*Plastics & Resins*, March, 1945, p. 11
H.F. Heating	A. G. Robiette	*Iron & Coal Trade Review*, October 6, 1944, p. 491
New Developments in Plastics for Aircraft	D. M. Buchanan	*Royal Aeronautical Society, Journal of*, 1944, p. 48
Radio Heating		*Wireless World*, February, 1944, p. 41
Radio Heating	L. L. Langton	*Wireless World*, March/June, 1944, p. 70
Dielectric Heating	L. Hartshorn	*Wireless World*, January, 1945, p. 2
Thermal Conduction with Radio Heating	H. Hearne	*Wireless Engineer*, August, 1944, p. 377
H.F. Heating		*Thermex Brochure* (Girdler Corp.), 1942
H.F. Heating	R. R. Baker and C. J. Madsen	*Paper Trades Journal*, 1944, p. 73
H.F. Heating Applications for Textiles	H. E. Reed	*Textile World*, August, 1944, p. 96
H.F. Heating Oscillators	W. C. Rudd	*Electronic Industries*, July, 1944, p. 96
The Principles of H.F. Heating	L. Hartshorn	*Chem. & Ind.*, September 9, 1944, p. 322
Heating Electronically		*G.E. Review*, July, 1943, p. 407
H.F. Gluing of Resins	W. Godfrey and P. H. Bilhuber	*Modern Plastics*, September, 1943, p. 89
H.F. Heating	L. M. Duryee	*Electrical World*, March 3, 1945, p. 72
Dielectric Heating Speeds Curing of Plastic Laminates	R. W. Auxier	*Product Eng.*, May, 1944, p. 299
H.F. Heating of Plastics	W. M. Witty	*Electronics*, June, 1943, p. 194
H.F. Heating	L. Hartshorn	*Royal Society of Arts, Journal of*, December 22, 1944, p. 38
Heating Plastics with Radio Current	C. N. Batsel	*Pacific Plastics Magazine*, 1943, p. 28
Applications of Vacuum Tube Oscillators to Induction and Dielectric Heating in Industry	J. P. Jordan	*Electrical Engineering*, 1942, p. 831
Shielding of Dielectric Heating Installations	G. W. Klingaman and G. H. Williams	*Electronics*, May, 1945, p. 106
Electronic Applications in Industry	W. MacD.	*Electronics*, May, 1945, p. 92
Electronic Heating, a Production Tool	V. W. Sherman	*Plastics & Resins*, March, 1944, p. 3
Chicago Conference on Induction and Dielectric Heating	Various	*Electronics*, March, 1945, p. 148
Load Rematching in Electronic Heating	Eugene Mittelmann	*Electronics*, February, 1945, p. 110
Employment of Electronics for Effecting Tire Vulcanisation	C. W. Vogt	*S.A.E. Journal Transaction*, March, 1945, p. 154
H.F. Heating	W. Nicholls	*Aircraft Production*, December, 1944, p. 585
The Place of Radiant, Dielectric and Eddy Current Heating	L. J. C. Connell, O. W. Humphreys, J. L. Rycroft	*Jour. I.E.E.*, to be published
Localised Heat Production on Living Tissue (cats and rats)		*Proceedings Exp. Biology*, *N.Y.*, June, 1943, p. 157
H.F. Heating Oscillators	W. C. Rudd	*Electronic Industries*, July, 1944, p. 96
Dielectric Heating	T. W. Dakin and R. W. Auxier	*Ind. Eng. Chem.*, March, 1945, p. 268
High Density thro' H.F.	V. W. Sherman	*Modern Plastics*
Automatic Tuning Systems for Preheating Plastics		*Electronics*, December, 1944, p. 115
Production, Applications and Transfer of Heat	Various	*Chem. & Met. Eng.*, May, 1944, p. 97

TITLE	*AUTHOR*	*REFERENCE*
SEAM WELDING, SPOT WELDING, SPOT GLUING, SOLDERING		
Welding		
The Welding of Thermoplastic Materials by R.F. Currents	H. P. Zade	*Plastics*, March, 1944, p. 100
Seam Welding of Plastics	W. C. E. Barnes	*Welding*, November, 1944, p. 509
R.F. Welding of P.V.C. Film	S. C. Mitchell	*Plastics*, December, 1944, p. 559
The Welding of Thermoplastics	G. Haim	*Plastics*, January, 1944, p. 24
An Electronic Sewing Machine	C. N. Hoyler	*Electronics*, August, 1943, p. 90
Radio Sewing Machine for Plastics	W. M. Witty	*Electronic Industries*, June, 1943
Sheet Plastics Seamed by Radio Current	C. N. Hoyler and G. H. Brown	*Plastics*, 1943, p. 349
Electronic Welding of Glass	E. M. Guyer	*Electronics*, June, 1945, p. 92
Welding Research	W. C. E. Barnes	*Welding*, April, 1944, p. 197
Seam Welding of Plastics	W. C. E. Barnes	*Welding*, November, 1944, p. 509
Packaging by Welding	H. P. Zade and W. E. C. Barnes	*Welding*, June, 1945, p. 199
Electronic Circuits for H.F. Welding	A. Vang	*Electronics*, December, 1943, p. 168
Electronic Brazing and Soldering	H. U. Hjermstad	*Electronics*, March, 1945, p. 148
Soldering		
High Speed Soldering with R.F. Power	J. P. Taylor	*Electronics*, February, 1944, p. 114
Gluing		
Spot Welding with Glue	I. F. Laucks	*British Plastics*, 1943, p. 169
Spot Gluing		*British Plastics*, October, 1944, p. 453
R.F. Gun for Spot Gluing Wood	J. P. Taylor	*Electronics*, November, 1943, p. 106
MOULDING		
Heatronic Moulding	V. E. Meharg	*Modern Plastics*, 1943, p. 106
A New Process of Moulding Using H.F.	G. Dring	*Plastics*, January, 1944, p. 10
H.F. Heating	A. E. L. Jervis	*Electrical Review*, May 26, 1944, p. 728
H.F. Heating	A. E. L. Jervis	*Electrician*, December 29, 1944, p. 577
R.F. Heating Speeds Plastic Moulding	J. P. Taylor	*Electronics*, September, 1943, p. 102
Progress in Heatronic Moulding	V. E. Meharg and A. P. Mazzucchelli	*Modern Plastics*, June, 1944, p. 108
Theory and Practice of Industrial Electronic Heating	J. P. Jordan	*G.E. Review*, 1943, p. 675
H.F. Preheating	G. Dring	*British Plastics*, January, 1944, p. 13
Heatronic Moulding	V. E. Meharg	*British Plastics*, 1943, p. 10
Electronic Preheating in Plastic Moulding	M. Lorant	*Electronic Engineering*, 1944, p. 448
R.F. Speeds Heating of Moulded Plastics	L. M. Duryee	*Electrical World*, March, 1944, p. 110
Moulding with R.F.	W. M. Witty	*Modern Plastics*, May, 1943, p. 83
Heatronic Moulding	V. E. Meharg	*Modern Plastics*, November, 1943, p. 106
H.F. Heating of Plastics		*British Plastics*, November, 1943, p. 322
H.F. Heating Solves Moulding Problems	L. L. Dawson	*Modern Plastics*, August, 1944, p. 114
Developments in Moulding Equipment	G. W. de Bell	*Soc. Plast. Industry*, May, 1944
A New Method of Moulding Thermo-Plastics		*B.E.A.M.A. Journal Chem. Ind.*, Feb., 1945
Short Waves and Transfer Moulding	J. P. Moran and G. P. Bohrer	*Modern Plastics*, June, 1944, p. 116
TIMBER SECTION		
Heating Wood with R.F. Power	J. P. Taylor	*Trans. A.S.M.E.*, April, 1943, p. 201
R.F. Technology in Wood Applications	G. F. Russell and J. W. Mann	*Trans. A.S.M.E.*, August, 1944, p. 563
Laminated Wood as an Insulator	A. E. L. Jervis	*Electronic Engineering*, February, 1944, p. 365
H.F. Heating	A. E. L. Jervis	*Electrical Times*, January 13, 1944, p. 36
H.F. Heating Sets Glue in Laminated Aircraft Spars	J. P. Taylor	*Electronics*, January, 1944, p. 96
R.F. Heating for Fabricating Wood Aircraft	J. P. Taylor	*Electronics*, March, 1944, p. 108
H.F. Current in Plywood Production	H. W. Young	*Electrical News & Engineering*, September 15, 1943, p. 34
H.F. Heating in Plywood Manufacture		*Aero Research Bulletin*, June, 1943
H.F. Bonding of Laminated Wood	H. W. Perry	*Aircraft Engineering*, May, 1944, p. 147
Heat Conduction Problems in Presses Used for Gluing of Wood	G. H. Brown	*Proc. I.R.E.*, October, 1943, p. 537
The History of Plywood	A. E. L. Jervis	*Practical Engineering*, March 24, 1944, p. 248
Electrostatic Heat for Resin Bonding	G. H. Brown	*Modern Plywood*, Nov., 3, 1943, p. 182
R.F. Heating of Aircraft Spars		*Electronics*, February, 1944, p. 150
Fabricating Wood Aircraft Spars	J. P. Taylor	*Electronics*, April, 1944, p. 102
R.F. Heating Applied to Wood Gluing	R. A. Bierworth and C. N. Hoyler	*Proc. I.R.E.*, October, 1943, p. 529
R.F. Heating Speeds Plywood Bonding	J. P. Jordan	*Electronics*, 1942, p. 79
Present and Future Applications of Laminated Densified Wood	A. E. L. Jervis	*British Plastics*, November, 1944, p. 478
H.F. Moulding of Plywood Cylinders	C. C. Brumleve	*Plastics & Resins*, January, 1945, p. 5
Accelerated Wood Bonding		*Aircraft Production*, January, 1945, p. 7
FOOD SECTION		
Electronic Sterilization in the Package	V. W. Sherman	*Modern Packaging*, 1944, p. 99
Electronic Dehydration of Foods	V. W. Sherman	*Electronics*, February, 1944, p. 94
Dehydration of Food by R.F. Energy	V. W. Sherman	*Electrical Comm.*, 1943, p. 125

Radio Heating and Mass Production Soldering

By CHRISTOPHER E. TIBBS, A.M.I.E.E.*

DURING the war period, radio-frequency heating has been successfully employed for many soldering operations which previously had to be performed manually, often as slow and tedious processes. At this time, when many industries are being re-equipped for post-war processes, it is opportune to review the possibilities which have been opened up by this technique.

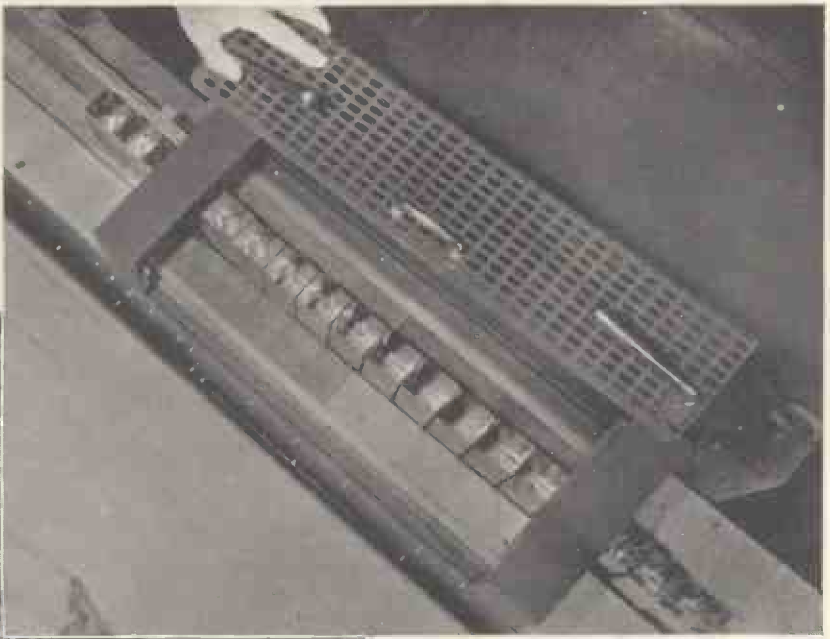


Fig. 1 (above). Overall arrangement of the soldering conveyor assembly, showing the oil-filled tank condenser projecting below the conveyor housing.

Fig. 2 (top right). Cans passing through the application coil. The protective guard has been lifted.

While a few soldering operations will always have to be performed by hand, there are many others which are ideally suited to the new method. As chance would have it, some of the most difficult hand-soldering operations turn out to be the simplest when tackled by radio heating. For example, one of the most irritating operations in the manufacture of tin-plate condenser cases is the soldering into position of the terminal bushes—this is an ideal radio-frequency conveyor application. An almost equivalent task is that of soldering into position the silver surfaced ceramic inserts now being used to bring leads through the tin-plate containers of tropical transformers and other components. Also under investigation is the possibility of using the radio-frequency methods for soldering the end-caps on to the silvered glass tubes now being used to seal tubular condensers for the Tropics.

Quite apart from the sealing of tropical components, there are numerous applications of an equally straightforward nature. The soldering into position of air-spaced trimmer condenser vanes, lugs on to

---

* Head of Industrial Department, Rediffusion Limited.

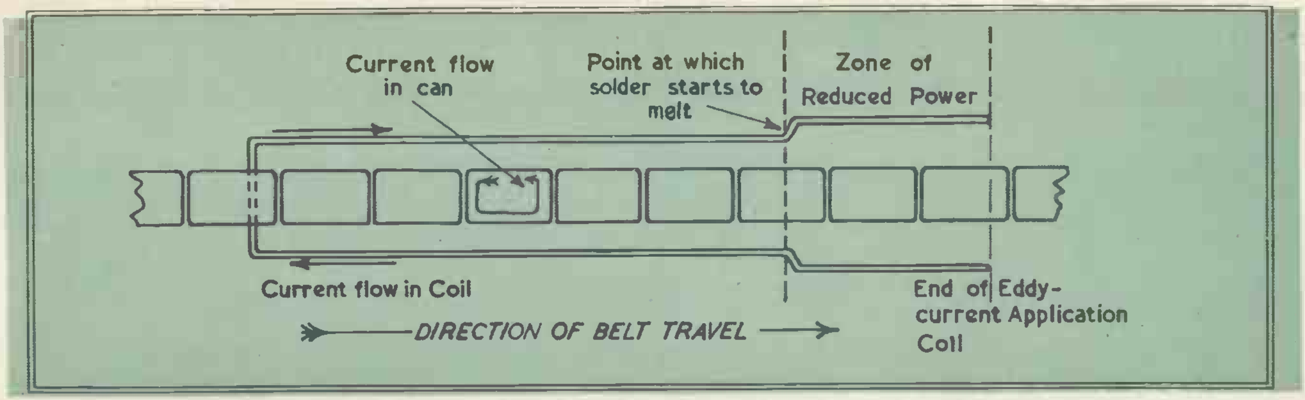


Fig. 5. Shaping of eddy-current application coil to prevent overheating of tin-plate while solder is running.

cables and wires into the ends of the larger cartridge-type fuses, are all applications for radio-frequency soldering. While some may not be suitable for conveyor flow production handling, the majority can be undertaken on a fully mechanised basis.

Soldering of Tin-Plate Containers

One of the more obvious operations which can be performed by the radio-heating method is that of soldering the ends on to tin-plate containers of all types. A typical equipment of this type has been in successful day and night operation at a Ministry of Supply factory since late last summer. This fully-mechanised conveyor which was designed and built by Rediffusion Engineers, handles some 1,200 tin-plate containers every hour.

Before the adoption of radio-frequency soldering, the production line had been laid out for hand-soldering methods. At this stage the following times were recorded for the various operations involved:

1. Assembly of can body and ends into jig, 30 seconds.
2. Soldering the two ends to the can body, 150 seconds.
3. Flowing solder up the seam running the length of the can body, 30 seconds.
4. Soldering a centre tube into position, 30 seconds.

As a production speed of 600 completed containers per hour had to be maintained, it is apparent from the above times that working a 60-minute hour, thirty girls were required for the first two operations, and five each for both the third and fourth operations. As the bulk of the time was being devoted to soldering the ends to the container body, it was decided that this operation should be undertaken by means of radio heating.

It was ultimately found—when the radio-heating equipment was installed—that the first operation could be dispensed with and the second performed at the required rate by four girls, who assembled and gauged the containers for length, loaded them on the conveyor, and, after inspecting the finished product, packed them into trays.

The Containers

A view of the container is given in Fig. 3. Its overall dimensions are 4½ in. long, 2¼ in. wide, 1⅞ in. deep. It will be noted that it consists of three sections which have to be soldered together within close limits. With the aid of the exploded view it is possible to follow the way in which this particular problem was tackled.

Firstly, one end-cap was assembled to the body of the container, and a formed ring of resin-cored solder 1/16 in. diameter slipped into the can. The lower end of the container was then passed through an induction heating coil, which raised its temperature. This caused the solder to melt, and, as a result of capillary attraction, to flow up the joint between the body and end-cap. When this joint was opened for examination, it was found to be consistently perfect, the solder flowing uniformly up the ⅛-in. overlapping lip and appearing in an even line around the top edge.

The Method Employed

It was found to be impracticable to solder both ends on to the can simultaneously, and it was therefore necessary for the radio-frequency heating equipment to handle each container twice—some 1,200 cans per hour or one can every three seconds. To begin with tests were made with a view to completing the soldering operation within this time. It was found, however, that the rapid heating involved caused the end-caps to distort, often by as much as ¼ in. This distortion was due to the widely different temperatures produced between various parts on the tin-plate container.

It was therefore decided that the only successful method of procedure was that of heating the containers slowly. The time necessary to produce a satisfactory and undistorted job was ultimately found by experiment to be some 25 seconds.

The problem of the method which should be employed to produce soldered cans at the rate of one every three seconds—when each required 25 seconds for processing—could have been solved in two ways. Firstly, some 10 cans could have been heated simultaneously in a static multi-position heating coil assembly. Secondly, the cans could be placed on a moving conveyor belt, so arranged that there were always 10 cans in process of being heated. That is to say, 10 cans which were always within the field of the induction heating coil.

In the former method, 10 containers would be completed as a batch every 25 seconds, while in the latter, the containers would come off the conveyor belt at a steady rate of one every three seconds, each container having received an identical heating cycle of some 25 seconds duration.

Various Difficulties

Practical tests on these two alternative methods soon brought to light a very important factor in favour of the latter system, namely, the difficulty of applying a perfectly uniform amount of heat at each of the ten positions in which the individual cans were being treated. It was found that if one position received slightly more power than another, the surface of tin-plate on the can in this position was discoloured. The conveyor belt method showed an immense advantage, in that every single container went through exactly the same heating cycle. It was therefore simply a matter of adjusting the power input and the belt speed until all the cans emerged from the eddy-current coil with an even flow of solder all the way round the junction between the end-cap and body.

The next problem to arise was due to the fact that the temperature reached by the can faces nearest to the heating coil was higher than that of the other two faces. As a consequence there was a tendency for the tin-plate to discolour on these sides before the solder had run freely all the way round the can. This tendency was eliminated by shaping the eddy-current coil as shown in Fig. 5. With this coil contour, the power applied to the cans once the solder had reached melting temperature was reduced to just that which was necessary to hold them constant at this temperature. In this way the solder was held in a molten condition sufficiently long to ensure that it had time to flow evenly all the way round the seam, without at the same time overheating the tin-plate.

Radio-Frequency Generator

The generator used to supply the radio-frequency power delivered some 3 kW at a frequency of 9 Mc/s. The circuit used in this generator consisted of a simple self-oscillator using two ACT9 valves in push-pull. Coupled into the oscillator tank coil was a single turn of copper strip some 10 in. wide. The two ends of this very tightly-coupled single turn were brought out directly to terminals on the inside of the conveyor framework. One terminal was connected to the end of a ¼-in. diameter water-cooled copper coil which was located at the same level as the conveyor belt. This coil, which was shrouded and isolated from the cans by means of a Mycalex cover, consisted of a single turn some 20 in. long by 3¼ in. wide.

The other end of this eddy-current work coil was connected to the live terminal of an oil-filled tank condenser variable between some 200 $\mu\mu$F and 1,000 $\mu\mu$F. This condenser, which was specially designed for the purpose, was rated at a voltage of 6,000 and a radio-frequency current of 100 amps. It was found that when operated at these ratings, the loss due to the finite Q of the transformer oil (between 10,000 and 20,000) and internal resistance losses, resulted in the temperature of the condenser reaching some 50° C. after six to eight hours' running time. The conveyor itself consisted of a woven glass belt some 2 in. wide. The good electrical properties of this belt avoided the possibility of damage due to dielectric heating, and at the same time overcame any danger that the heated containers would burn the conveyor. The belt speed, which was variable between fairly wide limits, was normally some 3 ft. 9 in. per minute.

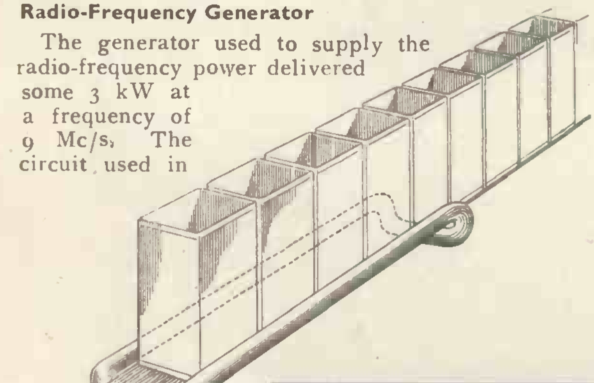
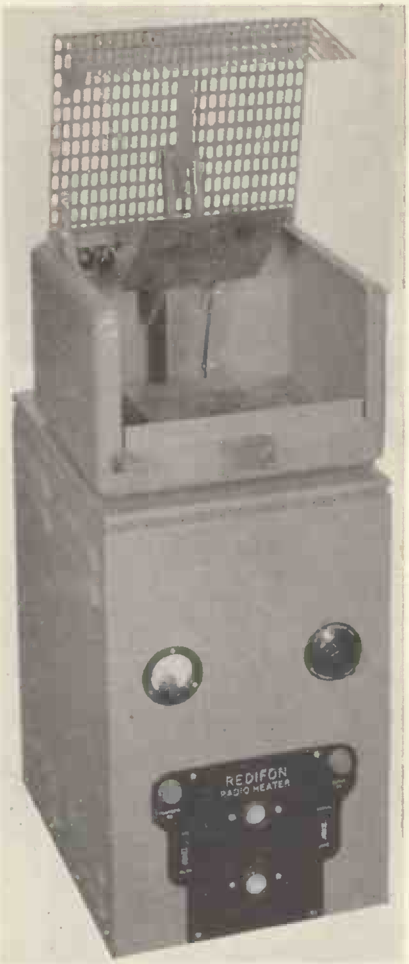


Fig. 3 (right). Component parts of container.

Fig. 4 (above). Sketch showing shape of heating coil.

A ¼-kW H.F. Generator



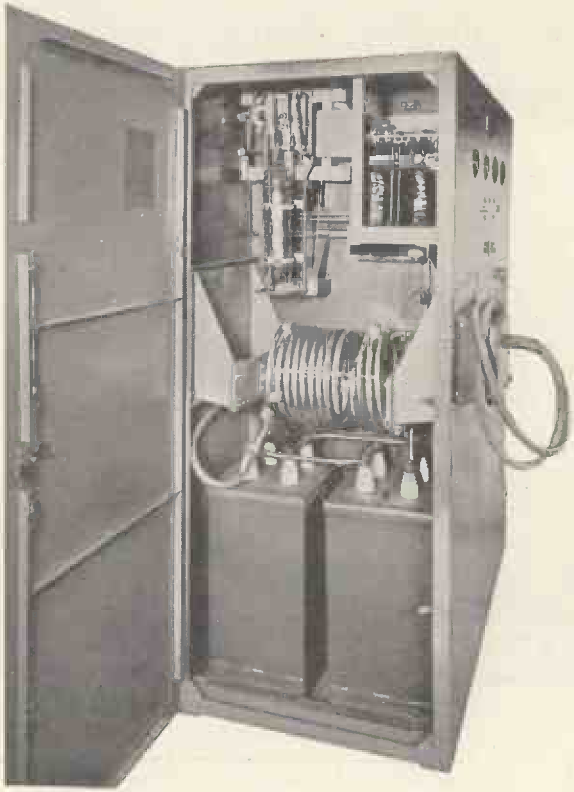
Front view of generator with lid lifted to show electrodes.

A small radio frequency generator, complete with heating chamber, suitable for dealing with a wide variety of materials including plastics and rubber.

By means of an ingenious mechanism the closing of the heating chamber lid brings the top electrode squarely down on to the load regardless of its thickness. As soon as the material has reached the preheating temperature the power supply circuit-breaker is automatically tripped, and the operator is notified by the extinction of a pilot light. The generator frequency is approximately 30 Mc/s. with a power output of 300 watts.

—Rediffusion, Ltd., Broomhill Road, S.W.18.

A New Induction Heating Equipment



A TYPICAL Induction Heating equipment, Type T.10, made by The Electric Furnace Company Ltd., Weybridge, England, is illustrated on this page.

The front view (below) shows the right-hand front door removed, giving access to the six hot cathode mercury vapour rectifier tubes. This door is interlocked with the isolating switch in the bottom right-hand panel as it gives access to high tension apparatus. Before it can be opened, the isolating switch has to be turned to the "off" position, which renders the whole of the equipment safe to handle.

The door at the bottom of the cubicle in the centre gives access to certain instruments and relays mainly for maintenance purposes, and here the highest voltage is safe to handle; this door is therefore not interlocked. The number of meters on the main panel at the top has been kept to a minimum, so as not to confuse unskilled operators.

The whole of the equipment has been designed as an industrial tool and for use in factories where the labour is mainly unskilled. The cubicle is ventilated on a "Plenum" system whereby air is drawn in through a renewable filter on the right-hand side and is delivered under pressure to the various parts of the equipment requiring it; oscillator, valve and rectifiers.

The photograph on the right shows the main tank coil, tank condenser, filament transformer and oscillator valve. The valve is of the silica envelope type with a dissipation rating of 4½ kW, mounted in a special carrying stirrup. The filament transformer is provided with a special starting circuit to prevent damage to the valve filament due to the application of too high a voltage when cold. The main tank coil contains anode and grid sections for the Hartley feed-back circuit. The coil is water-cooled and is mechanically arranged so that the output leads (shown at the front of the cubicle) may be taken out from the back of the cubicle should this be desired. This is achieved by turning the whole of the coil assembly round. The tank condensers are of the oil-immersed mica-dieletric type with substantial insulation and clearances to allow for industrial operation for long periods without attention. The door giving access to the oscillator compartment is also provided with an interlock in the same manner as the rectifier door; a special feature of the Castell keys being that they cannot be withdrawn once the doors are open. Without a duplicate set of keys it is therefore practically impossible to overcome the interlocking action. The Hartley circuit is of the self-tuning type allowing a wide variety of inductor coils to be used. The operator is therefore left in effect with only the on-off control to initiate, and even this may be done, if required, by a time switch. The control may be from the push buttons or the panel, or by remote switch as determined by the position of the control unit.

The leads to the inductor or work coil are water-cooled, thus enabling heavy currents to be carried without undue difficulty.

The standard equipment is rated to operate at about 500 kc/s., but other frequencies may be used where this is justified by metallurgical or thermal considerations. The equipment takes a balanced load from 3 phase 50 cycles at any reasonable mains voltage, the input power under full load conditions being about 15 kVA. This may be exceeded for short periods where the heating cycle justifies a variable duty rating.

DESIGN CHART:

Calculations for Dielectric Heating by High Frequency Current

By A. J. MADDOCK, M.Sc., F.Inst.P., A.M.I.E.E.*

1.0. Introduction

TO enable full design information to be worked out for heating a dielectric material by high-frequency currents, the interrelation of the following factors must be determined:

(a) Energy; (b) power; (c) time; (d) temperature rise; (e) weight or volume; (f) thickness of material; (g) specific heat; (h) density; (i) dielectric constant; (j) power factor of the material; (k) R.F. voltage; and (l) frequency.

Items (g), (h), (i) and (j) are physical properties of the material being heated which in some instances are available from published data, (e) and (f) are related to the size and weight of the load, (a), (b), (c) and (d) correlate the energy required and the rate at which energy is to be supplied for a given temperature rise, while (k) and (l) represent the necessary electrical conditions to be met to achieve the desired rate of heating.

These design sheets have been prepared to enable all the necessary factors to be obtained readily by inspection and furthermore to show, at a glance, the interdependence of many of the factors.

The charts are based upon the fundamental formulæ of Equations (2) to (7) which hold good for the case of heating between plane-parallel electrodes. As the heating process is carried out by electrical means it is convenient to express energy in watt-hours and power in watts, and it should be noted that the values obtained for these factors are those theoretically necessary for raising the temperature of the load itself; they do not include for any losses by conduction, convection or radiation. As a guide, if it is not desired to calculate these losses accurately, an addition of 10 per cent. to 20 per cent. might be made to cater for such conditions. The relation between watt-hours and British thermal units is: 1 watt-hour = 3.41 B.Th.U. and 1 B.Th.U. = 0.293 watt-hour.

2.0. Symbols Used

The following symbols are used:

W_g = energy/gm. in watt-hours/gm.
W_i = energy/cu. in. in watt-hours/cu. in.
P_g = power/gm. in watts/gm.
P_i = power/cu. in. in watts/cu. in.
t = time in mins.
θ_c = temperature rise in °C.
θ_F = temperature rise in °F.
d_c = thickness of load in cms.
d_i = thickness of load in ins.
S = specific heat in cals/gm/°C. or B.Th.U./lb/°F.
ρ = relative density.
K = dielectric constant.
$\cos\phi$ = power factor of the load material.
E = R.F. voltage across the load.
E' = R.F. voltage across the electrodes.
f = frequency of R.F. voltage in Mc/s.
d_{ac} and d_{ai} = total thickness of air gaps between load and electrodes; in cms. and ins. respectively.
A_c = area of load within electrodes in sq. cms.
A_i = area of load within electrodes in sq. ins.
C = capacity in $\mu\mu$F.

In explanation of some of these symbols, it is to be noted that the volume of the load is taken as the full volume occupied and does not refer only to the solid or liquid matter contained therein, *e.g.*, if the material is in powder form the volume is that of the container. Similarly, the thickness, relative density, dielectric constant, and power factor all refer to the load as contained within that volume, *e.g.*, again referring to a powder load the density may be half that of the actual solid material, the remainder of the volume being composed of air. As the specific heat refers to mass only the value is the same for compressed or powdered material.

The voltage gradient (E/d_c or E/d_i) across the load is that across the volume being considered. The variation of power absorbed is taken care of in the variation of ρ, K and $\cos\phi$ as mentioned above.

If any air-gap is provided between electrodes and load this will be equivalent to increasing the thickness of the load by Kd_{ac} or Kd_{ai} and so the electrode voltage E' must be higher than that required across the load; the relation is given by:

$$E' = E\left(1 + \frac{Kd_{ac}}{d_c}\right)$$

$$\text{or} \qquad E\left(1 + \frac{Kd_{ai}}{d_i}\right) \qquad \ldots\ (1)$$

The air-gap may thus have a large influence if K is high.

3.0. Fundamental Formulae

Energy:

$$W_g = 1.16 \times 10^{-3} \,.\, S \,.\, \theta_c \text{ watt-hours/gm.} \quad \ldots\ldots\ (2)$$

$$W_i = 1.05 \times 10^{-2} \,.\, S \,.\, \rho \,.\, \theta_F \text{ watt-hours/cu. in.} \quad \ldots\ (3)$$

Power:

$$P_g = 5.58 \times 10^{-7} \,.\, f \,.\left(\frac{E}{d_c}\right)^2 .\, \frac{K\cos\phi}{\rho} \text{ watts/gm.} \quad \ldots\ldots\ (4)$$

$$P_i = 1.42 \times 10^{-6} \,.\, f \,.\left(\frac{E}{d_i}\right)^2 .\, K\cos\phi \text{ watts/cu. in.} \quad \ldots\ldots\ (5)$$

Time:

$$t = 60\ W_g/P_g \quad \ldots\ldots\ (6)$$

$$t = 60\ W_i/P_i \quad \ldots\ldots\ (7)$$

The importance of the voltage gradient should be noted as it is the square of this term that appears in the formulæ. Thus an increase of voltage is more effective than an increase of frequency in raising the power input and reducing the time of heating. Also if the voltage has a fixed value the time of heating will increase with the square of the thickness of the load and is independent of its area.

---

* Standard Telephones and Cables, Ltd.

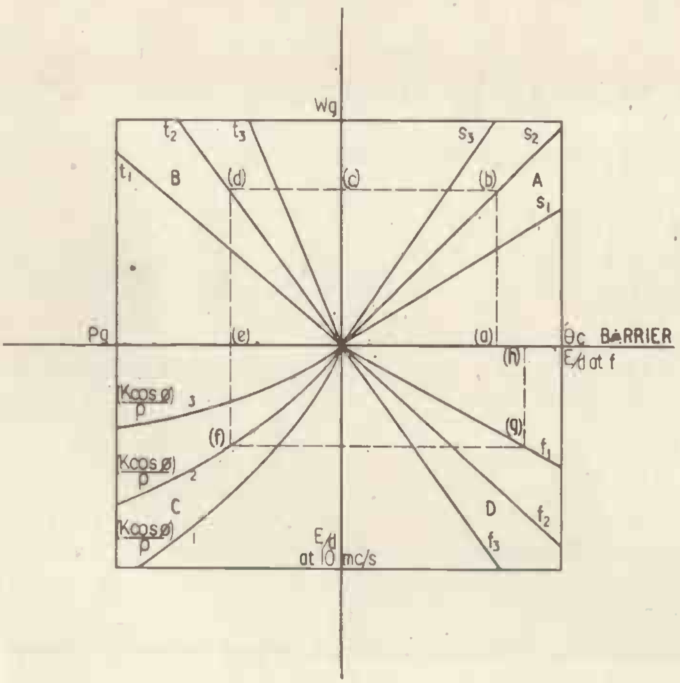


Fig. 1. Illustrating method of utilising the charts of Figs. 2 and 3.

4.0. The Design Charts

Two separate charts are given, one expressing the several factors in terms of weight in grammes, dimensions in cms., and temperature in °C., while the other is in terms of volume in cu. ins., dimensions in ins., and temperature in °F. Each chart is complete in itself.

In each chart there are four quadrants, marked A, B, C and D; it is permissible to pass across any axis separating quadrants except that between A and D, which has been marked "Barrier." One may start in any quadrant and proceed both ways to the barrier, depending upon what conditions are known.

Quadrant A relates energy and temperature rise, quadrant B relates energy, power and time, quadrant C relates power and voltage gradient at a frequency of 10 Mc/s., while quadrant D enables the voltage gradient at any other frequency than 10 Mc/s. to be obtained. Quadrant D is thus only used when the frequency is different from 10 Mc/s.

Fig. 1, taken in conjunction with the following examples, illustrates the method of use.

Example 1

A certain material has a specific heat of 0.4, density 1.0, dielectric constant 4.0 and power factor 0.05 (hence $K \cos \phi/\rho = 0.2$). It is desired to heat 500 gms. of this material, in a thickness of 5 cms., through a temperature rise of 110° C. in 2 mins. Find the energy, power and voltage required at a frequency of 15 Mc/s.

For this we use the chart of Fig. 2. Starting in quadrant A at $\theta_c = 110$°C. (point (a) on Fig. 1), proceed vertically to meet the specific heat line 0.4 (at (b)). From this point proceed horizontally to the W_g axis (at (c)), obtaining the energy per gm. of 0.038 watt-hours; the total energy for the 500 gms. is thus 19 watt-hours. Continue horizontally, into the B quadrant, to meet the 2 minute line (at (d)) and then travel vertically downwards to the P_g axis (at (e)) obtaining a value of 1.15 watts/gm.; the total power required for the 500 gms. is thus 575 watts.

Continue downwards into quadrant C to meet the $K \cos \phi/\rho = 0.2$ line (at (f)) and then proceed horizontally across into the D quadrant to meet the 15 Mc/s. line (at (g)); from here proceed vertically to the "Barrier" axis (at (h)) obtaining a value of 720 volts/cm. for the voltage gradient. As the thickness of the load is 5 cms. the total voltage required across the load is 3,600 volts.

If an air-gap of 0.4 cm. were provided above the load, Equation (1) shows that an electrode voltage of 4,750 volts is necessary.

Example 2

A high-frequency generator is to be operated at an output voltage of 3,000 V at 5 Mc/s. A material, having a specific heat of 0.5, density 0.7, dielectric constant 6.0 and power factor 0.5, is to be heated through a temperature rise of 150° F.; the material is 6 ft. × 3 ft. × 2 in. thick, hence the volume is 5,200 cu. in. Find the energy, power and time for this operation.

For this we use the chart of Fig. 3. Commencing, in quadrant A, at $\theta_F = 150$° F., proceed as before, *via* the $S\rho = 0.35$ line to the W_1 axis obtaining a value of 0.6 watt-hours/cu. in.; the energy for the total volume is thus 3,120 watt-hours. Continue horizontally into quadrant B, drawing the line across all the time lines.

Now start again in quadrant D on the "Barrier" axis at $E/d_1 = 3{,}000/2 = 1{,}500$ volts/in. and proceed *via* the 5 Mc/s. line across into quadrant C to cut the $K \cos \phi = 3.0$ line. Proceed thence vertically, cutting the P_1 axis at a value of 21 watts/cu. in., thus obtaining the total power required of 109 kW, and project upwards into the B quadrant to cut the horizontal line previously drawn from the W_1 axis. Where these intersect, the time of heating will be obtained; the value of this example is 1¾ mins.

Reference to Fig. 4 shows that, for the length of 6 ft., a frequency of 5 Mc/s. is the maximum that could be used, if connexion is made to the end of the electrodes.

5.0. Simplified Data

In addition to having the charts available for careful calculation, it is often convenient to be able to estimate quickly the power, etc., required and the following useful mnemonics are given:

(a) *Materials with specific heat of* 0.35, *e.g.*, most moulding resins, relatively dry wood.

4 watt-hours per 100 gms. per 100° C. temp. rise, *e.g.*, 250 watts for 1 min. per 100 gms. per 100° C. temp. rise.

(b) *Materials with specific heat of* 0.4 *and relative density of* 0.63, *or other values if their product is* 0.25, *e.g.*, wood of moderate moisture content.

0.5 watt-hours per cu. in. per 100°C. temp. rise.

Or 850 watt-hours per cu. ft. per 100° C. temp. rise, *e.g.*, 8 kW for 5 min. per cu. ft. per 100° C. temp. rise.

(c) *To bring water (specific heat 1.0) to boiling point* (100° C.) assuming a rise of 85° C.

10 watt-hours per 100 gms. or 0.1 kWh per Kg., *e.g.*, 250 watts for 2½ mins. per 100 gms.

Expressed in terms of pound weight:

0.5 kWh per lb.

(d) *To evaporate water (latent heat 537 cals/gm.) at* 100° C.

Approx. 0.3 kWh per lb. *e.g.*, 0.3 kW for 1 hour per lb.

(e) *To thaw ice (latent heat 80 cals/gm.) at* 0° C.

Approx. 45 watt-hours per lb. *e.g.*, 0.5 kW for 5 mins. per lb.

6.0. Properties of Some Materials

The physical constants of some materials with which high-frequency heating has already been employed are given here for handy reference. These are average values likely to be obtained.

Physical Constants of Some Materials

Material	Specific heat S	Rel. density ρ	Di-electric const. K	Power factor $\cos\phi$	Freq. at which K and $\cos\phi$ measured	Usual temp. to which heated °C.
Phenolic resin ; wood-flour filled						
Preform	0.35	1.08	3.8	.041	1–30 Mc/s.	120–140°C.
Powder	0.35	0.57	1.8	.029	,,	,,
Urea resin ; cellulose filled						
Preform	0.4	1.25	5.5	.025	1–30 Mc/s.	100–120°C.
Acrylic resin ; placticised						
Moulded	0.35	1.19	2.8	.020	1 Mc/s.	80°C.
Polyvinyl chloride	0.3	1.35	6.5	.120	50 c/s.	130°C.
Vinyl acetate						
Moulded	0.24	1.4	6.0	.050	1–30 Mc/s.	
Preform	0.24	—	3.7	.045	,,	
Cellulose acetate						
Moulded	0.32	1.33	3.5	.032	1–30 Mc/s.	240°C. fuse 200°C. preheat
Phenolic glue						
Liquid	0.8	1.23	10	>.50	10 Mc/s.	140°C.
Urea glue						
Liquid	1.0	1.30	26	.85	10 Mc/s.	100°C.
Spruce wood						
0% moisture	0.32	0.37	2.2	.052	45 Mc/s.	100–140°C.
6% ,,	0.36	0.40	2.5	.070	,,	
10% ,,	0.39	0.42	3.2	.090	,,	
Beech wood						
0% moisture	0.32	0.56	2.0	.02	10 Mc/s.	100–140°C.
6% ,,	0.36	0.61	3.0	.11	,,	
10% ,,	0.39	0.63	5.0	.38	,,	

7.0. Additional Electrical Conditions

The capacity of the load need only be calculated to determine the value of inductance required to tune to resonance.

For dimensions in cms.:

$$C = 0.089\ K \cdot \frac{A_c}{d_c}\ \mu\mu\text{F} \quad \ldots\ldots\ldots\ldots (8)$$

and when the dimensions are in inches:

$$C = 0.225\ K \cdot \frac{A_i}{d_i}\ \mu\mu\text{F} \quad \ldots\ldots\ldots\ldots (9)$$

A factor which must be considered, particularly on loads of large area or length, is that standing waves may be formed on the electrodes resulting in uneven heating of the load. This will be a function of frequency in relation to the length of the load.

It is advisable that there shall not be a change in voltage between any two points along the length greater than 10 per cent. and preferably the change should be less than this as it is equivalent to a power variation of 20 per cent. Fig. 4 is given to show the maximum frequency that may be used for any length with a 10 per cent. voltage change.

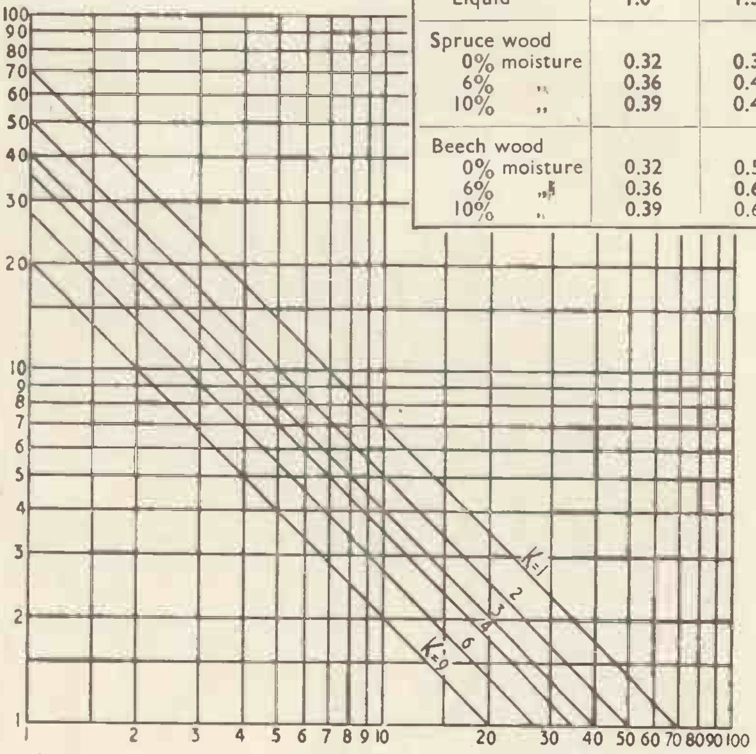
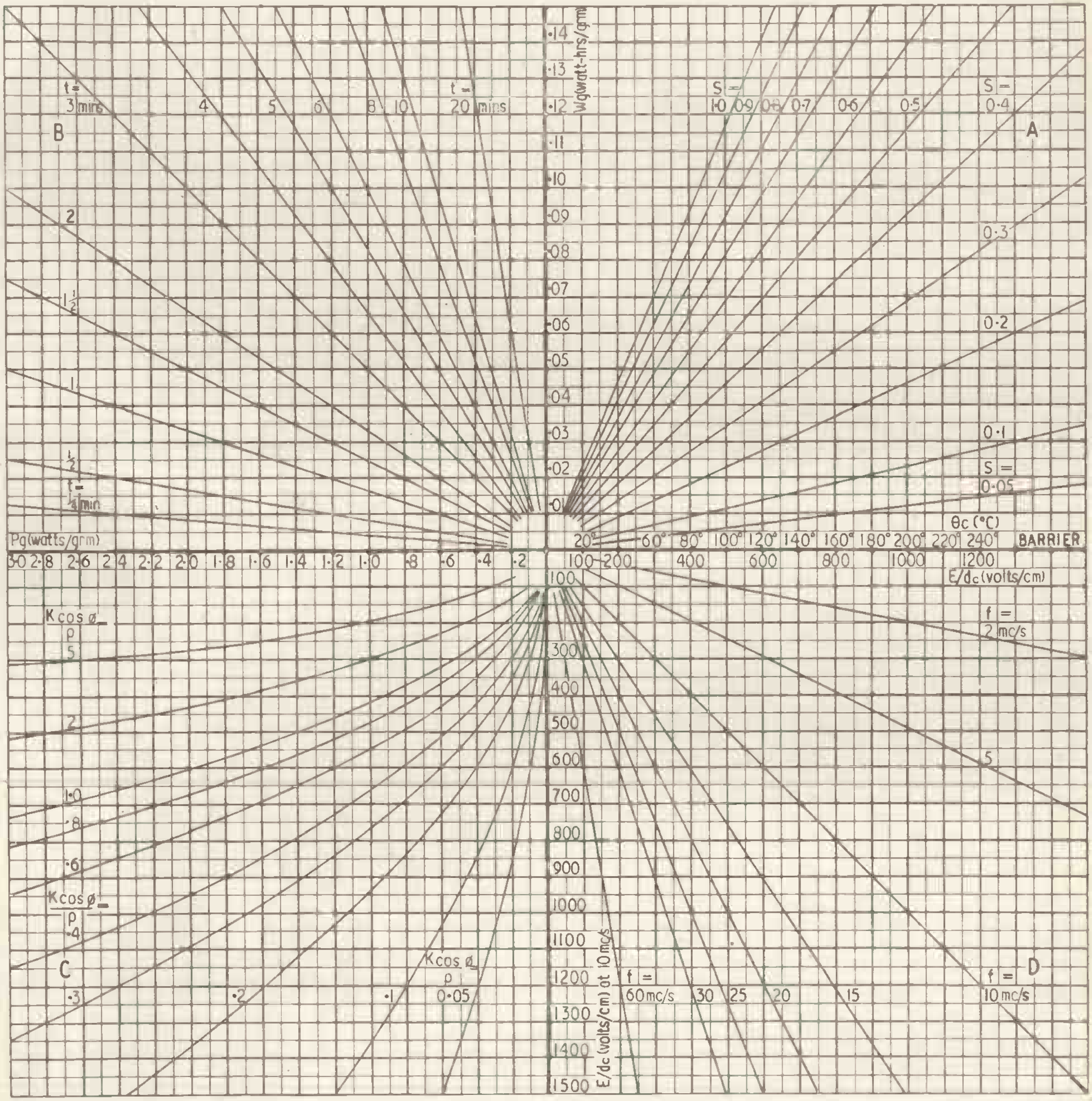


Fig. 4. **Maximum frequency possible for different lengths of load if the voltage variation is 10 per cent.**

Heating chart for weight in grammes, dimensions in centimetres, and temperature in degrees Centigrade

Fig. 2

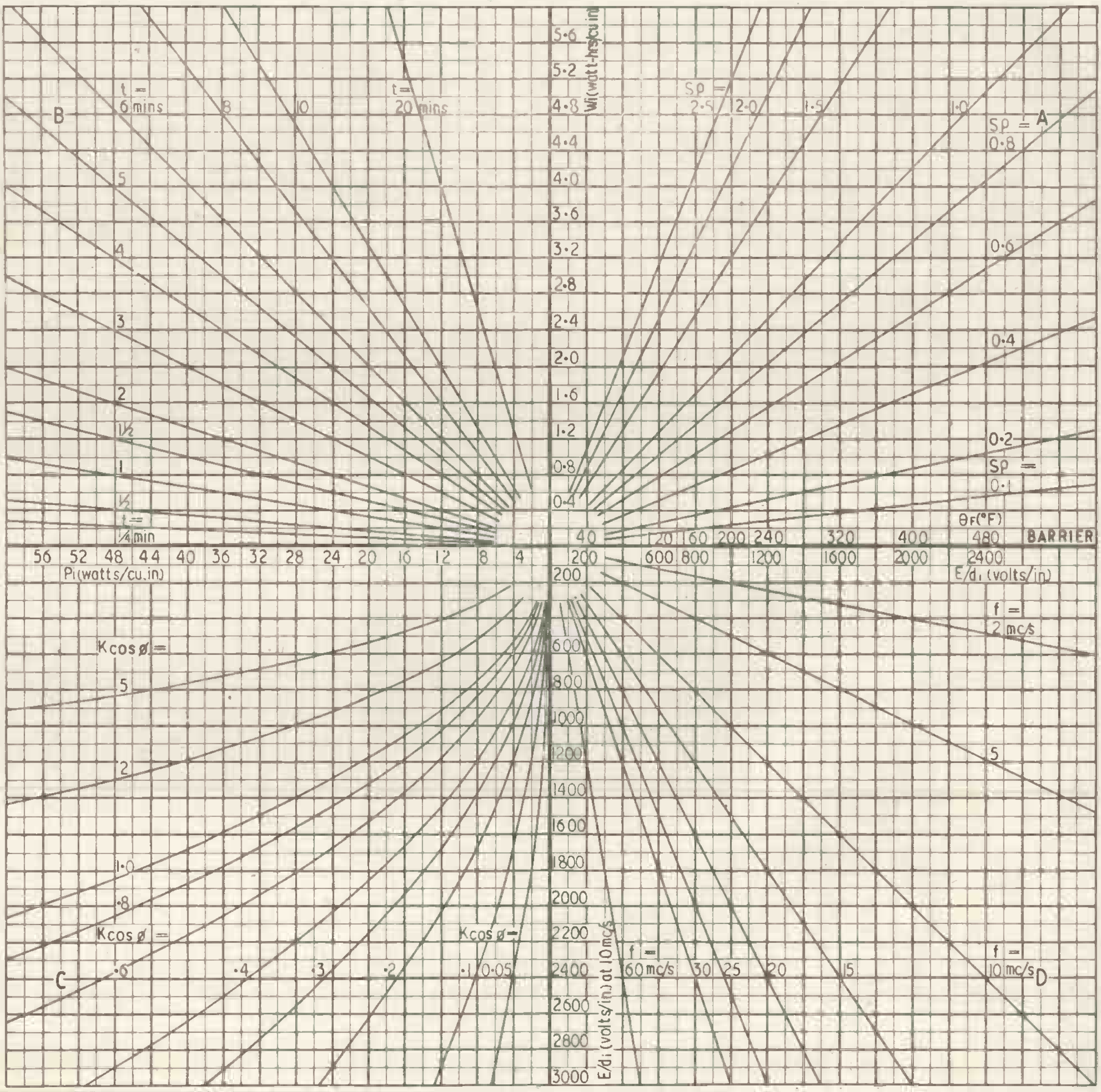


Note: In reading the chart, it is permissible to pass across any axis in either direction except that marked "Barrier."

Quadrant A = Energy v. Temperature rise
Quadrant B = Energy v. Power for various time intervals
Quadrant C = Power v. Voltage gradient at 10 Mc/s.
Quadrant D = Voltage gradient for other frequencies

Heating chart for volume in cubic inches, dimensions in inches, and temperature in degrees Fahrenheit

Fig. 3



Note: In reading the chart, it is permissible to pass across any axis in either direction except that marked "Barrier."

Quadrant A = Energy *v.* Temperature rise
Quadrant B = Energy *v.* Power for various time intervals
Quadrant C = Power *v.* Voltage gradient at 10 Mc/s.
Quadrant D = Voltage gradient for other frequencies

Magnifying Details in a Complex Waveform

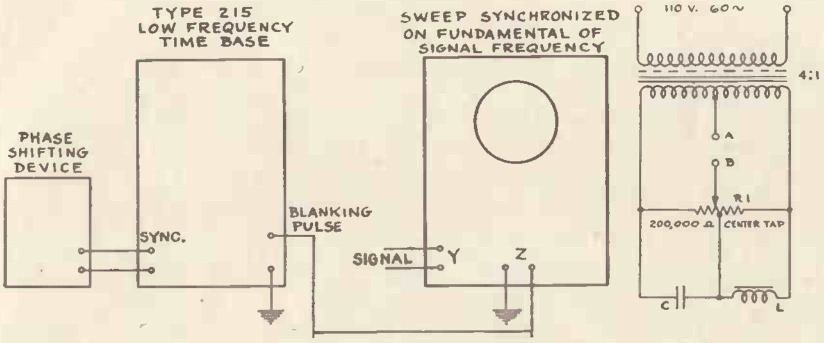


Fig. 1. (a) Schematic diagram of circuit, and (b) details of phase-shifting circuit.

To expand the image on the screen of a cathode-ray tube, either the amplitude or the frequency of the sweep may be increased.

The amplitude expansion is limited by the overload of the amplifier, and the sweep frequency, if increased, makes the trace complicated and practically impossible to interpret.

In a method described by R. Feldt,* a high speed sweep is used to magnify the trace, and the confusion is avoided by singling out one time element and suppressing the rest. This is accomplished by applying to the grid of the tube short positive pulses at a repetitive rate equal to the fundamental frequency of the signal under observation. The tube is biased to cut-off and is illuminated only during the pulse. Any part of the oscillogram may thus be made visible by shifting the phase of the pulse by the usual phase-shifting device.

In the circuit described (Fig. 1a), a separate low-frequency time base is used to provide the pulses, synchronised to the frequency of the waveform under examination. Phase shift is obtained from capacitance-inductance combination designed to resonate the fundamental frequency. By means of R_1 the phase of point B (Fig. 1b) can be varied from + 90° to − 90° with respect to A.

Fig. 2 (a) shows a complex 60 c/s. wave, (b) shows a section of the same wave after the pulse has been applied to the tube, and (c) the expansion of the section by increasing the sweep frequency to 5,000 c/s.

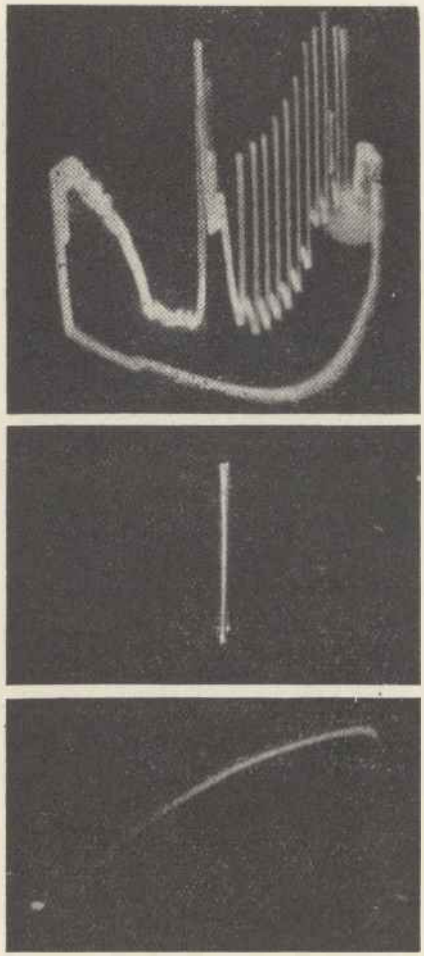


Fig. 2. (a) (Top). Complex 60 c/s. waveform. (b) Section of wave, and (c) the same section expanded.

---

* *The Du Mont Oscillographer*, Jan.-Feb., 1945.

Automatic H.F. Heating Control

An automatic tuning device in which small thyratrons and a reversible motor are used to provide continuous automatic tuning of an electronic power generator was described at a meeting of the Philadelphia Section of the Institute of Radio Engineers by Dr. W. M. Roberds (RCA Victor).

These so control the oscillator that any predetermined power can be fed to the work continuously, regardless of changes in the electrical properties of the work material produced by heating.

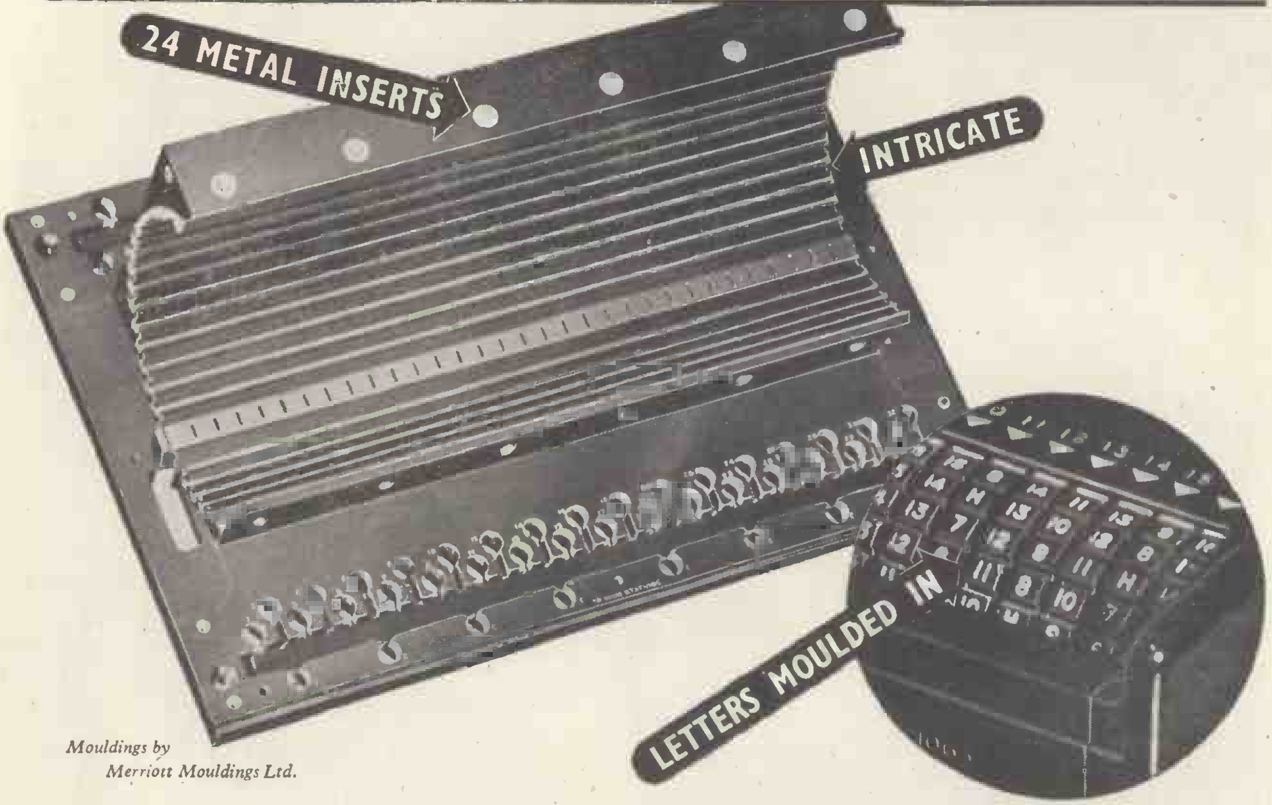
The tube anode current and grid current are used in opposite arms of a bridge and the thyratrons are actuated to keep the bridge balanced by rotating the reversible motor, which in turn varies an inductance in series with the load. The load circuit is closely coupled to the tank circuit and all tuning is done on one slope of the first hump of the resonance curves. The load circuit is never completely tuned, but always presents a capacitative reactance to the tank circuit.

At the same meeting Dr. Roberds gave a demonstration of RCA's automatic 2-kilowatt electronic power generator (RCA Model 2-B), designed with a compact built-in heating chamber and applicator assembly for dielectric heating.

Induction Heating in Radio Tube Manufacture

The radio electron-tube industry was one of the first to use induction heating extensively. The metal parts of electron tubes must be heated to 500° to 1,500° C. during evacuation in order to liberate gases occluded in the parts. Since the parts are in a vacuum and are usually surrounded by a glass bulb, induction heating is the ideal method. The heating coils are usually made to fit the bulbs and may be used either on stationary evacuation systems or on rotary systems. Other similar applications are "getter" flashing and vacuum-firing systems. Still other applications are in sealing metal to glass, in brazing tube parts together, and in welding. In all of these applications the chief advantages are accurate control and speed of heating.
—*E. E. Spitzer, in "Trans. Electrochem. Soc.,"* 1944.

Study this bomb-load pre-selector



Mouldings by
Merriott Mouldings Ltd.

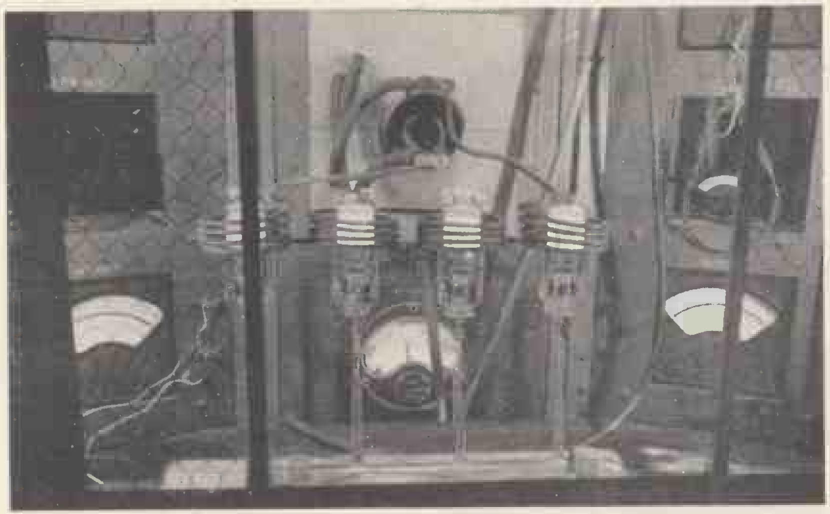
EXCEPT for the metal cover it is moulded entirely from Bakelite Moulding material X20/5HD. No fewer than 24 metal inserts are successfully incorporated in the base and the letters and numbers in the contact discs are moulded in and not engraved. Apart from the immense saving in production time thus effected, its great advantage over previous types is that **it saves over 2½ lb. in weight.**

TREFOIL
BAKELITE PLASTICS
REGD. TRADE MARKS

Pioneers in the Plastics World

T32

BAKELITE LIMITED · 18 GROSVENOR GARDENS · LONDON S.W.1 · TELEPHONE: SLOANE 9911



Exhaust bench, showing anodes of four 60 W triodes being heated by H.F. induced current.
—*M.O. Valve Co.*

Power Valves for H.F. Heating Equipment

By F. E. HENDERSON, A.M.I.E.E.*

IT is agreed that the type of circuit to be used in R.F. heating equipment will follow generally established lines, embracing a self-excited power oscillator and its associated power rectifier. It should be possible, therefore, to standardise the basic circuit arrangements, although modifications are inevitable to cater for safety devices, and the choice of components may vary in covering the required ranges of frequencies and voltages accompanying the circuit design.

This article is not intended to enter into detail on the technical aspect of the nature of the circuits to be used, but merely to indicate the possibility, indeed, the desirability, of approaching this new field for the employment of higher power valves, with a long-term outlook.

When we visualise a valve used as a generator of radio frequency oscillations, one of the aspects of interest to the designs engineer will be the efficiency at which it operates. This efficiency is briefly expressed in terms of the useful A.C. power output which can be obtained for a given D.C power input. The valve can, of course, be considered as a D.C./A.C. converter, and the loss in the valve itself which determines its efficiency depends upon a number of factors, one of the most important of which is the frequency at which it is desired to produce the A.C. power. Roughly, such efficiency for conventional valves can be taken as about 70 per cent. when frequencies not exceeding 3 to 4 Mc/s. are assumed, but each valve, according to its design characteristics, has its own maximum frequency of operation.

The figure of efficiency below which it is not usually considered economic to use a valve may be assumed to be of the order of 30 per cent. The limitation at low frequencies is usually determined by the basic bulk of the circuit components, which in the case of long-wave oscillators is often very considerable. At high frequencies it is determined by the dimensions and design of the valve. Great care has to be taken in the design of the grid seal of high frequency power valves, as in such cases the radio frequency grid currents may become very considerable due to the low reactance of the inter-electrode capacitances at very high frequencies. The grid lead-out wires must, therefore, be of adequate dimensions to carry these currents without overheating, which would crack the glass at the grid seal, etc.

Another point of engineering interest is the necessity for the intelligent use of protective devices, bound up with the circuit employed. For example, many large power valves require to be cooled by a forced cooling system such as by circulating water (as applied to certain designs of external anode water-cooled valves) or by a flow of air under pressure through fins attached to the anode of types designed for forced air cooling. In such cases it is necessary to ensure that the valve cannot be worked unless the cooling system is in operation, or, in other words, the power input cannot be applied unless means are taken to direct the heat generated at the anode away from it in a suitable manner. Any failure of the cooling system should also imply a cessation of the applied power.

In many large valves, the electron-emitting filament consists of a hairpin or multiplicity of hairpins of tungsten wire, and the current required to heat it to operating temperature may be as high as several hundred amperes. The resistance of such a filament when cold is less than one-tenth of the resistance when hot. The application of the full operating voltage to a filament of this sort when cold may result in instantaneous currents of several thousand amperes which would cause complete destruction of the filament.

It is essential, therefore, to apply the filament voltage in stages to prevent the valve being ruined by excessive filament current before the filament itself has had time to heat up. Suitable interlock devices are also necessary on high power oscillating valves whereby it is impossible to put on to the valve the full power input, or, in other words, apply the anode voltage, before the filament has had time to attain its normal operating temperature.

It will, of course, be realised by the industrial user that all electronic devices are consumable articles with a definite life, and the expectation of valve life under given running conditions is therefore likely to prove a very important factor in computing the overall cost of running R.F. heating equipment, after having

---

* The General Electric Co., Ltd., London.

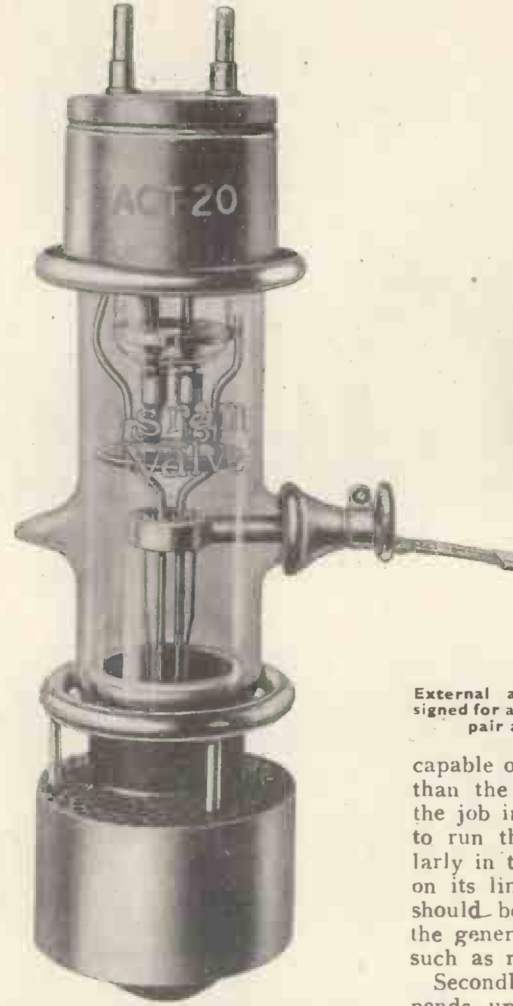
External anode fitted with radiator for natural cooling or forced air cooling, depending on the output required. Usually employed for outputs up to 4-5 kW per push-pull pair at frequencies up to 15 Mc/s.

taken into account the running costs covered by the actual kW consumption in power.

It is clear, then, that the industry will soon appreciate, if it does not do so at the outset, that prime cost is likely in the long run to take second place to the more important factor of freedom from breakdown under conditions which are likely to prove even more onerous than those ruling under the conditions of a radio transmission station.

Choice of Oscillator Valve for Specific Applications

We can now turn to a more detailed consideration of the class of valve which will be required to meet any particular needs as regards R.F. power output and frequency.



External anode short-wave valve with radiator for forced air cooling. Designed for output up to 4 kW at frequencies up to 100 Mc/s.

Taking first the question of R.F. output required, this is defined as the actual power which can be delivered into the load circuit, and depends upon the type of load and the efficiency of the coupling between valve and load circuit. The actual power which the valve is called upon to deliver can be ascertained either by calculation or by a trial of an experimental setup. In any case, the latter method will probably be necessary as it is not always easy to take into account all losses by calculation only.

Owing to undefined losses, variation in supply voltages and overload conditions liable to occur, it is advisable to make a choice of valve which is, by the maker's rating, capable of rather greater R.F. output than the actual estimated figure for the job in question; it is undesirable to run the oscillator valve, particularly in these industrial applications, on its limit of rating, but a margin should be in hand to take care of the general unforeseen considerations such as referred to above.

External anode air-blast-cooled triode designed for an output up to 500 W per push-pull pair at frequencies up to 100 Mc/s.

Secondly, the choice of valve depends upon the frequency of R.F. currents which would be required, and, as stated earlier in this article, such frequencies depend to a wide extent on the type of work and may vary from 100 kc/s. upwards to 100 Mc/s.

For most purposes, the range may be narrowed to frequencies lying between 10 and 50 Mc/s., although with the extension of experimental work, the use of higher frequencies than 50 Mc/s. may be more widely required, particularly at the lower powers.

The third consideration is that of the available power supply for providing the D.C. input to the oscillating valve.

To take a specific example, let us assume that the actual power which is required to be generated in the load circuit is, say, 3.5 kW. Assuming the factor of safety referred to above, it would, therefore, be desirable that a valve capable of a minimum output of 4 kW should be allowed for.

The next consideration is that of frequency, and we will assume that for the particular work in hand this is required to be 15 Mc/s. Reference to the maker's lists indicates that (with the assumption of suitable power input) two valves of the Osram ACT9 type in a push-pull circuit would give the required output in power and would oscillate at the frequencies called for with an efficiency of not less than 75 per cent., *i.e.*, 75 per cent. of the input power supplied to the valves would be available as useful R.F. output. This order of efficiency indicates an input of 5.4 kW, and, referring to the maker's characteristics of the valve in question, the suitable operating conditions for an input of 5.4 kW require an applied anode voltage of 7,500 volts and current of 0.72 amp.

This brings us to the design of the power stage to provide this output, and again referring to the maker's lists, the use of six mercury-vapour rectifiers type GU21 in a 3-phase full-wave circuit is found to give this output. This gives the basis for a suitable design of oscillator and power unit, and other designs for different orders of R.F. power can be computed in the same way.

Continuing the design example referred to above, we find that with the ACT9 operating at the power and frequencies called for, no forced air cooling is necessary, the natural convection and radiation from the specially designed anode radiator being adequate. Should the design call for a larger dissipation of heat, the choice may lie between forced air cooling and circulating water cooling.

In the case of water cooling, it is very necessary that a circulating water system is used employing only pure soft water, which is pumped round the system and suitably cooled through its circuit. The use of tap water or other water which has not been purified and softened is extremely undesirable and should always be avoided, as its use will lead to corrosion and "furring" of the anode, resulting in a rise in operating temperature and possibility of earlier valve failure due to gassing.

While the water cooling system requires the above precautions and an external pump, the forced air cooling also requires a suitably designed air-circulating system and fan, so that the choice of one or other of the two systems is probably one of economics and convenience for the particular application in mind. If forced air cooling is employed, the use of a slow speed induction motor is generally desirable to reduce noise and wear and tear of the motor.

A suggestion is made that as far as possible H.F. heating equipment should fall into certain well-defined groups of frequency and power output, and, for example, it might be assumed that the following grouping would cover the requirements of industry as at present known:

	R.F. Output	Frequency (Mc/s. max.)
1	100 W	100
2	0.5–1 kW	50
3	4 kW	50
4	15–25 kW	20
5	75 kW	10

Other demands may arise for output powers considerably in excess of 75 kW and such equipments are already in use in the U.S.A.

Each one of the above groups would, of course, have its associated power rectifier unit so that it should be possible to limit the numbers of alternative valve types to a narrow range and so not only economise in production cost, but ensure that so far as possible such valves could remain in production over a long period and save complications which might arise later in maintenance.

In the initial stage of this development it is probable that types of power valve developed for the radio transmission field will have to be employed, but as experience is gained as to the optimum frequencies and power required to meet the wide variation in the nature of the work, it should be possible to adopt a standardised line of valves (*i.e.*, standardised in regard to frequency of operation and power output) for any one manufacturer, although it is possibly too much to hope that this standardisation could be applied in a national way owing to the different techniques adopted by different valve manufacturers.

Taking the valve aspect alone as one of the vital components, it is, therefore, desirable that the type of valve chosen for each group such as previously outlined should be backed by experience and adequate life test cover on the part of the valve manufacturer, when applied in continuous service at a given power dissipation and frequency.

Ediswan Valve Type EFH350

This is a transmitting valve of 500 watts dissipation with low-capacity anode and grid leads for use at high frequencies. Although primarily designed for use in H.F. generators it is equally suitable for intermittent working. The maximum operating frequency is 50 Mc/s. under full load conditions and with reduced loading the frequency can be increased to 100 Mc/s.

Specification:

Filament voltage	23
Filament current (amps)	16
Maximum anode volts ...	4,000
Working anode volts	3,000
*Amplification factor	43
*Slope (mA/V)	3.2
*Impedance (ohms)	13,500

*At V_a 3,000, I_a 90 mA.

Capacitances:

Anode-Grid	7.7 $\mu\mu$F
Anode-cathode	2.0 $\mu\mu$F
Grid-cathode	10.0 $\mu\mu$F

Further particulars and characteristic curves can be obtained from the Special Valve Dept., Radio Division, The Edison Swan Electric Co., Ltd., Brimsdown, Middlesex.

Longitudinal or Transverse Heating?

By D. I. LAWSON, M.Sc.

An investigation into the relative efficiencies of longitudinal and transverse heating applied to the gluing of wood

IT has been suggested that more rapid heating of the glue lines in wood is attained if the electric field were applied along the line of the glue (longitudinal heating) instead of across it (transverse heating). The following article shows the relative efficiencies of the two methods and the conditions under which maximum efficiency can be obtained.

1. Longitudinal Heating

Assume that N blocks of wood are to be glued together, then there will be $N - 1$ glue lines. Then we may represent the block (Fig. 1a) by N condensers C_w in parallel representing the wooden sections and $(N - 1)$ condensers C_g in parallel representing the glue lines. Both these condensers will have parallel resistances R_w and R_g owing to the fact that the wood and glue are both imperfect dielectrics. The equivalent electrical circuit is shown in Fig. 2a. One of the conditions for maximum power being transferred from the oscillator to the wood is that the reactive components must disappear in the load. This is accomplished by tuning the load to resonance with an auxiliary inductance. The equivalent circuit then becomes purely resistive (Fig. 2b).

The fraction α_L of the total radio frequency power dissipated in the glue line will be

$$\alpha_L = \frac{\dfrac{R_w}{N}}{\dfrac{R_w}{N} + \dfrac{R_g}{N-1}} = \frac{1}{1 + \dfrac{N}{N-1}\,\dfrac{R_g}{R_w}} \quad (1)$$

If $\tan.\delta_w$ and $\tan.\delta_g$ are the power factors of the wood and glue respectively we have

$$\tan.\delta_w = \frac{1}{\omega C_w R_w} \qquad \tan.\delta_g = \frac{1}{\omega C_g R_g}$$

$$\frac{R_g}{R_w} = \frac{C_w \tan.\delta_w}{C_g \tan.\delta_g} \quad \ldots\ldots\ (2)$$

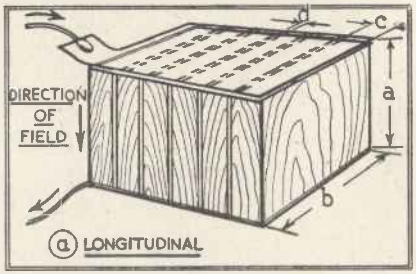


Fig. 1 (a).

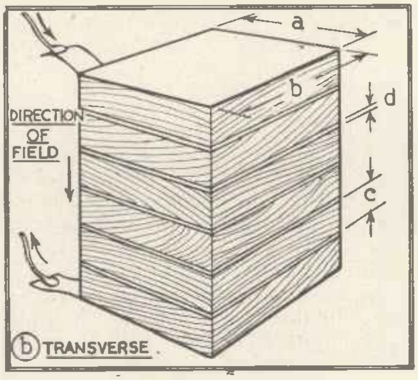


Fig. 1 (b).

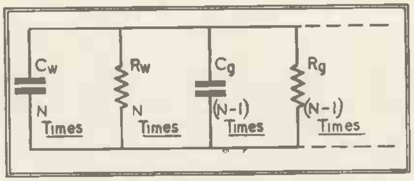
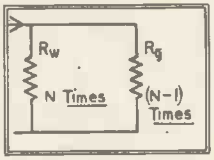
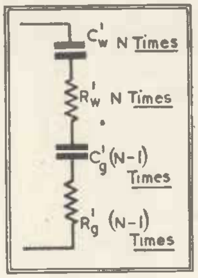
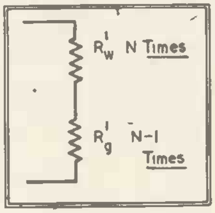


Fig. 2a (above).
Fig. 2b (right).
Fig. 3a (below).
Fig. 3b (lower right).







From the dimensions of the blocks given in Fig. 1a we have

$$C_w = \frac{\epsilon_w cb}{4\pi a} \qquad C_g = \frac{\epsilon_g bd}{4\pi a}$$

Where ϵ_g and ϵ_w are the dielectric constants of the glue and wood,

$$\frac{C_w}{C_g} = \frac{\epsilon_w c}{\epsilon_g d}$$

Substituting in (2) we get

$$\frac{R_g}{R_w} = \frac{\epsilon_w c \tan.\delta_w}{\epsilon_g d \tan.\delta_g}$$

Substituting for $\dfrac{R_g}{R_w}$ in (1) we get the fraction of power entering the glue to be

$$\alpha_L = \frac{1}{1 + \dfrac{N\epsilon_w c \tan.\delta_w}{N - 1\epsilon_g d \tan.\delta_g}}$$

This may be made to approach 1 if the second factor of the denominator is sufficiently diminished. To do this it would be necessary to have a glue with both a high dielectric constant and power factor. Increasing α_L by increasing d is, of course, not allowable if good joints are to be made.

2. Transverse Heating

Assume that the same blocks of wood as before are to be glued. The equivalent series circuit is shown in Fig. 3a and after tuning by Fig. 3b.

The fraction (α_T) of the applied power entering the wood is

$$\alpha_T = \frac{(N-1)R'_g}{NR'_w + (N-1)R'_g}$$

$$= \frac{1}{1 + \dfrac{N}{(N-1)}\,\dfrac{R_w'}{R_g'}} \quad \ldots\ldots\ldots\ldots\ (3)$$

Two H.F. Power Valves

MULLARD TX12-20W →

The valve illustrated is water-cooled and is shown complete with water jacket.

A forced-air-cooled version is available, where it is expedient to use this method of cooling. No additional cooling of the filament or grid seals is necessary in either case. At an anode voltage of 12 kV, the valve will provide 22 kW of R.F. power in a Class "C" oscillator circuit, the maximum frequency of operation being 20 Mc/s.

← **MULLARD TXS10-4,000**

This valve has a silica envelope, which allows a compact construction despite the maximum anode dissipation of 4 kW.

The valves have a pure tungsten filament, and a single valve in a Class "C" oscillator circuit will give an output of 7½ kW at an anode voltage of 12 kV. The maximum operating frequency is 20 Mc/s. It is possible, at the end of filament life, for the envelope to be opened and the filament renewed.

Now if $\tan.\delta_w$ and $\tan.\delta_g$ are the power factors of the wood and glue and since R' and C' represent series resistances and capacitances, the following relationships hold:

$$\tan.\delta_w = R'_w \omega C'_w \text{ and } \tan.\delta_g = R'_g \omega C'_g$$

$$\frac{R'_w}{R'_g} \doteqdot \frac{\tan.\delta_w}{\tan.\delta_g} \frac{C_g'}{C_w'} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

From the block dimensions (Fig. 1b) we have

$$C'_w = \frac{\epsilon_w ab}{4\pi c} \qquad C'_g = \frac{\epsilon_g ab}{4\pi d}$$

$$\therefore \frac{C_g'}{C_w'} = \frac{\epsilon_g}{\epsilon_w} \frac{c}{d}$$

Substituting this in (4) we have

$$\frac{R'_w}{R'_g} = \frac{\epsilon_g c \tan.\delta_w}{\epsilon_w d \tan.\delta_g}$$

Substituting this in (3), we have the fraction of power α_T entering the glue line as

$$\alpha_T = \frac{1}{1 + \dfrac{N}{(N-1)} \dfrac{\epsilon_g c \tan.\delta_w}{\epsilon_w d \tan.\delta_g}}$$

This differs from the expression for α_L in that the dielectric constants of wood and glue are interchanged in the expression. α_T could be made maximum by increasing $\tan.\delta_g$ and reducing ϵ_g.

Conclusion

Clearly the method to be recommended depends on the ratio of the dielectric constants of the wood and glue. If $\epsilon_g > \epsilon_w$ longitudinal heating would be preferred and *vice versa*. The dielectric constants of synthetic resins are high, *e.g.*, Aerolite 300 glue mixed with 5 per cent. G.B.M. hardener (by weight) has a dielectric constant of 26 immediately after mixing. The dielectric constant of wood is about 5, and therefore with synthetic resins longitudinal heating is advantageous.

It is interesting, finally, to insert some numerical quantities in the expressions for α_L and α_T. The power factor of Aerolite 300 under the conditions quoted is .7, while that of wood is about .05, and if, say, five pieces ($N = 5$) of ½-in. wood are to be glued together, the glue lines being .01 in. thick, we have

$$\alpha_L = \cdot 535$$
$$\alpha_T = .041$$

Longitudinal heating is thus about 13 times more efficient.

Another advantage of longitudinal heating is that in dealing with thick blocks it is possible in effect to reduce c by using a series of platens covering the glue lines only and missing the bulk of wood in between. (Fig. 4.)

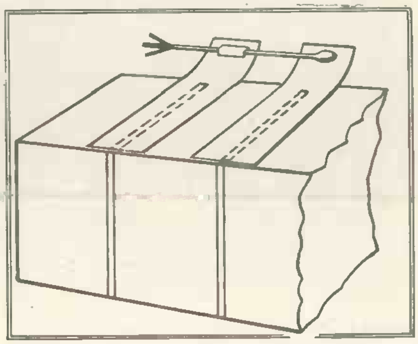


Fig. 4.

A New Type of Oscillating Crystal

By C. P. FAGAN, A.R.I.C.*

THE increased demand for oscillating crystals during the present war has led to investigations on the possibility of replacing quartz in certain applications by crystals of an artificial type. Rochelle salt (sodium potassium tartrate) has been known for many years as a good piezo-electric oscillator, and numerous crystalline compounds, mostly of an inorganic character, have been examined for piezo-electric effect. As well as this, there are a number of naturally-occurring crystals, such as tourmaline, which possess well-marked electrical properties. There is reason to believe that the phenomenon of piezo-electricity is in some way associated with molecular asymmetry. This asymmetry is particularly noticeable in the case of tartaric acid. While Rochelle salt has a high piezo-electric activity, its use is restricted owing to the effects of moisture and rather poor mechanical strength of the crystal. During an investigation of the tartrates, the writer found that lithium potassium tartrate was a crystalline compound with good electrical characteristics which could be obtained in large-sized crystals which had good mechanical strength, and which were not affected by atmospheric moisture. Such crystals are easily prepared by neutralising a solution of potassium hydrogen tartrate with lithium hydroxide, and crystallising the resultant solution. Small seed crystals may be obtained by allowing a portion of the solution to evaporate spontaneously. A seed crystal of suitable size, suspended by a hair or a very fine nickel wire in the saturated mother liquor, will grow quickly. There are no special precautions to observe during the period of growth beyond absence of vibration, and the maintenance of a fairly steady temperature. One of the interesting points about lithium potassium tartrate crystals is the ease with which they can be grown. Starting with a small seed crystal it is possible to obtain good-sized specimens in about a week.

A drawing of a typical lithium potassium tartrate crystal showing dimensions is given in Fig. 1.

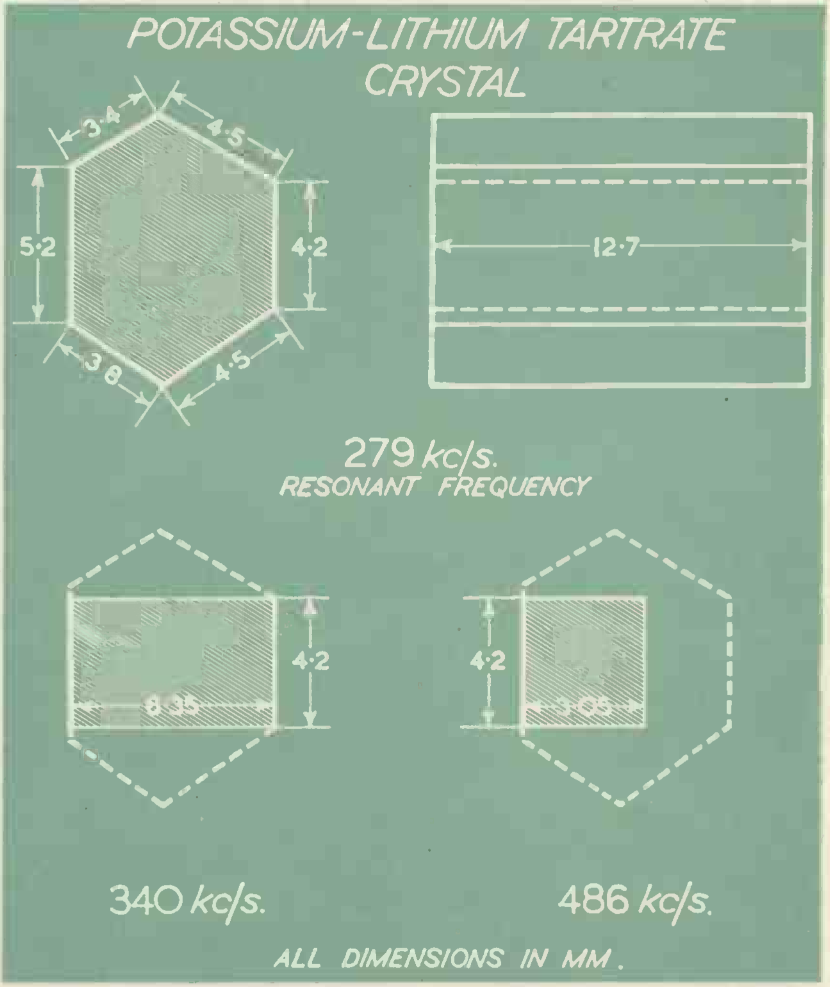


Fig. 1 (top). Typical crystal showing dimensions. Fig. 2 (left). Crystal cut for 340 kc/s. and Fig. 3 (right) cut for 486 kc/s.

With regard to mechanical properties it may be said that the crystal is slightly less hard than Mycalex. Cutting and filing the crystal shows a tendency to cleaving in several directions, one normal to the principal axis. The crystal was not affected by atmospheric moisture over a period of twelve months. It was found that the piezo-electric axis coincided with the principal axis and no piezo-electric effects were observable in directions normal to this. One resonance was observed in the crystal shown in Fig. 1. This was at 279 kc/s. Though overtones must have been present, damping due to crystal imperfections impeded their observations. Rough measurements showed that the 'Q' value was of the order of 2,000 in a circuit composing a heptode oscillator, requiring a series resonant impedance not greater than 0.1 megohm with the crystal standing vertically on one electrode with a top air gap of about .01 in. The fact that a crystal of such low 'Q' would oscillate in the above circuit indicates that the

(*Concluded on page* 652.)

---

* Marconi's Wireless Telegraph Co., Ltd.

Space Charge and Electron Deflections in Beam Tetrode Theory

Part 3—Conclusion

By S. RODDA, B.Sc., F.Inst.P.

Introductory

IN the preceding sections it has been shown that there are two results for knee voltage values, V_k and V_σ, given by Gill's theory and by the virtual cathode theory respectively. The latter value V_σ is much too high and must be rejected.

It has also been shown that the cumulative deflections of electrons at the grid and screen wires may be large, but that then the deflection theory cannot account for sharp "knees."

In the following section a modification of Gill's Equation is proposed, based on a combination of the space charge theory and the deflection theory.

8.1. The Effect of Electron Deflections on the Space Charge and the Current Distribution Between Screen and Anode

There are two cases to be considered:

(*a*) All the current is transported across the S-A space.

(*b*) Part of the current is reflected in the neighbourhood of the potential minimum, the remainder is transmitted to the anode.

8.2. Conditions of Full Current Transported to Anode

The current projected into the S-A space comprised between the angles θ_1 and $\theta_1 + d\theta_1$ is $I_s'(\theta_1)d\theta_1$. At a plane where the potential is V, the forward velocity u is:

$$\sqrt{\left(\frac{2\epsilon}{m}\right)}\sqrt{V - V\sin^2\theta}$$

and since $V\sin^2\theta = V_1\sin^2\theta_1$

$$u = \left(\frac{2\epsilon}{m}\right)^{\frac{1}{2}}\sqrt{V - V_1\sin^2\theta_1}$$

$$\approx \left(\frac{2\epsilon}{m}\right)^{\frac{1}{2}}\sqrt{V - V_1\theta_1^2}$$

The contribution $d\rho$ to the total space charge density is $-\dfrac{dI}{u}$.

To get the total space charge density this must be integrated over all angles.

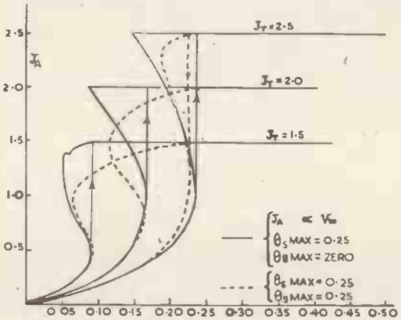


Fig. 14

If the distribution $I_s'(\theta_1)$ is expanded as a series in powers of θ_1, the integration can readily be performed. As an example, if the distribution is uniform from $-\theta$ to $+\theta$ we get:

$$\rho = \frac{I_A}{\sqrt{\frac{2\epsilon}{m}V_1\theta^2}}\sin^{-1}\sqrt{\frac{V_1\theta^2}{V}}$$

As an illustration, consider a potential minimum plane where $V = V_m = V_1\theta^2$, so that all the electrons are just transmitted.

The space charge density is then $\pi/2$ times as great as if an equal anode current density were transported by undeflected electrons. At higher values of V the multiplying factor will diminish to unity. The overall result is that somewhat less current can be transported than Gill's Equation indicates.

8.3. Current Division Occurs at a Potential Minimum: Part Only Reaching Anode

When the potential minimum is small enough the extremely deflected electrons will not even reach the potential minimum plane, but will be turned back to the screen. Only the electrons for which $V_1\sin^2\theta_1 < V_m$ will reach the anode. The returning electrons will add to the space charge density in the potential minimum to screen space, the more so since their forward and reverse velocities are diminished.

As in the virtual cathode case, the forward current is J_T, the return current is $J_T - J_A$ so that the total current at any plane is $(2J_T - J_A)$.

If for simplicity the effect of electron deflections on space charge is ignored—and to do otherwise makes the calculations very complicated—we can then write as in Equation 4, Section 5.

$$x_1 = x_a \frac{(1 + 2v_m)(1 - v_m)^{1/2}}{\sqrt{2J_T - J_A}} \quad \ldots\ldots\ldots (1)$$

Similarly for the potential minimum to anode gap,

$$x_2 = x_a \frac{(v_2 + 2v_m)(v_2 - v_m)^{1/2}}{\sqrt{J_A}} \quad \ldots\ldots (2)$$

so that on summation,

$$1 = \frac{(1 + 2v_m)(1 - v_m)^{1/2}}{\sqrt{2J_T - J_A}} + \frac{(v_2 + 2v_m)(v_2 - v_m)^{1/2}}{\sqrt{J_A}} \quad \ldots (3)$$

Now, if for a given value of J_T the distribution-in-angle of the electrons projected through the screen is known, J_A will be a known function of V_m, denoted by $f(V_m)$. If this is inserted in the equation, it will be seen that it determines V_2.

The results for $J_T = 1.5, 2.0, 2.5$ are shown as solid lines in Fig. 14, supposing that the entire deflection is at the screen, the maximum deflection being assumed to be 0.25 radian.

As one would expect, the result of giving V_m a positive value is to increase J_A for a given V_2 compared with the virtual cathode case—quite clearly more current ought to be transported across the screen-to-anode space when the electrons are not brought to rest, as at a zero potential minimum. The full current is attained at much lower values of V_2 so that the hysteresis loops are relatively small. Note that if J_A is put equal to J_T, Gill's equation is obtained, while if $V_m = 0$, the virtual cathode equation is obtained.

The dotted curves in Fig. 14 are drawn on the supposition that there is a maximum deflection at the control grid equal to the maximum deflection at the screen, instead of being zero. The characteristics at low values of I_A are not much altered, and W'_σ is scarcely shifted by this additional deflection. If $V_\sigma < V_1\theta^2$, however, *i.e.*, if the "knee voltage" is lower than the transverse electron velocity, measured in electron volts, the characteristics shoot upwards to current values lower than the full current. (This failure to reach full current may, of course, be accentuated by secondary electron loss from the anode.) If θ_g is approximately equal to θ_s the main effect is an alteration in shape and diminution in area of the loops at high values of I_A. Increasing θ_s to an optimum value greatly reduces the knee voltage to values well below the results given by the virtual cathode theory. Although the knee voltages are now in better accord with experiment, the predicted curves still do not rise quickly enough and in practice the infinitely steep portions are found to be shorter or absent.

The assumption is made in deriving Equation (3) (8.3) that the total current density at any plane lying between the potential minimum and screen is proportional to $(2I_T - I_A)$. This cannot be true near the potential minimum itself since some of the electrons must already have been turned back. In fact, the space charge density has its maximum value somewhere between the screen and the potential minimum, and gradually thins out as the potential minimum position is approached. This is offset by the fact that returning deflected electrons give an excess of space charge, since they move more slowly than deflected electrons across a given plane. For these reasons Equation (3) (8.3) cannot be claimed to be rigorous, but more precise calculations based on specific cases are not in notable disagreement with the knee voltage values given by this simplified theory.

9. Modifying Features

There are, however, several further features that a complete theory should take into account.

(1) *Thermionic Emission Velocities.*

Electrons will be transmitted through the barrier formed by the potential minimum even if this is several tenths of volt negative with respect to the cathode. If $V_1 = 100$ volts and $\theta_1 = 0.04$ radian, $V_t = 0.16$ volt; so that for angular deflections up to this magnitude the transverse velocities are comparable with the thermionic velocities. 20 per cent. of the current flow may be comprised within deflection angles from zero to 0.04 radian, consequently at small values of V_m the actual anode current depends on thermionic velocities as well as on the transverse velocities. The result of this is to steepen the initial rising part of the characteristics and to raise the value of I_A at which the curve begins to bend back.

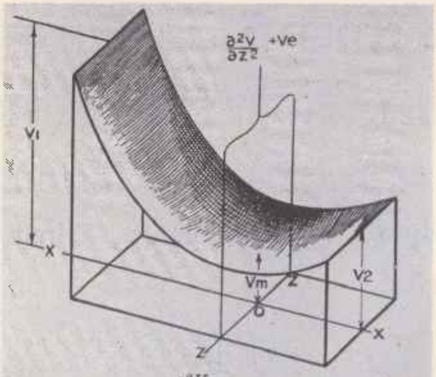


Fig. 15. Showing $\frac{\partial^2 V}{\partial z^2}$ positive in a beam of finite width

(2) *The Space Charge due to Secondary Electrons.*[6]

Although the potential minimum may present a barrier to the retrograde passage of secondary electrons, the secondary electrons emitted from and returning to the anode constitute negative charges in the potential minimum to anode space. The more copiously secondary electrons are emitted the deeper will be the potential depression they are able to produce. To some degree, therefore, secondary emission by producing space charge exercises a compensating action on the proportion which can travel back to the screen.

(3) *Multiple Trajectories through the Screen Plane.*

Below the knee voltage electrons will be reflected back through the screen, and after reversal in the screen-to-cathode space those which are not intercepted by the screen wires will re-enter the screen-to-anode space. At this traversal these electrons will be deflected, the new angular deflection being either added to or subtracted from the original deflection; in the latter case the electrons may now be able to reach the anode.

(4) *Effect of Finite Width of Beam.*

The results given are strictly applicable only to the plane case for beams of infinitely great cross-sectional area. At the edge of a semi-infinite beam Equation [1(2)] shows that the depression in voltage, due to space charge, is less than half the voltage depression in the interior of the beam. In general, for a beam of finite width, Poisson's Equation is required in its two-dimensional form:

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial z^2} = -4\pi\rho$$

In a section across the beam, V increases from the centre to the edges, $\partial^2 V/\partial z^2$ is positive as in Fig. 15, and hence for a given value of ρ, $\partial^2 V/\partial x^2$ is decreased. This means that even along the centre line of the beam, drawn from screen to anode, the curvature of the V versus x curve is diminished, and therefore for a fixed screen and anode potentials the potential minimum, if formed, will not be so low as with an infinitely wide beam.

(5) *The Effect of Electron Deflections in the S-A Space.*

The electrons moving along the edges of a beam will be repelled by the space charge due to the beam, which may or may not be compensated for by the electrostatic field due to the earthed plate system. In addition to transverse velocities u_y, electrons will acquire transverse velocities u_z, and when

$$u_y^2 + u_z^2 = \frac{2\epsilon}{m} V$$

the electrons will be brought to rest in the forward direction.

The simplest case to consider is that of the plane-parallel electrode arrangement with the space charge density insufficient to produce a potential minimum between screen and anode. All electrons will be collected by the anode when $(u_y^2 + u_z^2)$ at the anode plane is less than $\frac{2\epsilon}{m} V_2$.

If we suppose that $u_y = ay_0$, $u_z = bz_0$ where y_0, z_0 are co-ordinates giving the point on the cathode from which the electrons are emitted, while a and b are constants, it follows that for an electron to be captured by the anode it must have been emitted within the ellipse given by:

$$a^2 y_0^2 + b^2 z_0^2 = \frac{2\epsilon}{m} V_2$$

The area of this ellipse is directly proportional to V_2—hence the emitting area from which the captured electrons originate, and therefore the anode current is initially directly proportional to V_2. If the current density

ADVERTISEMENT OF THE TELEGRAPH CONDENSER CO. LTD.

is sufficient to produce a potential minimum, the situation is more complicated, especially when the height of the potential minimum varies across the beam width. At low values of V_2 the current is greater than that calculated on the assumption of an infinitely wide beams—and in general the effect helps to remove hysteresis loops.

Summary

The main points of this survey may be summarised:

1. In beam tetrodes retrograde secondary emission is minimised by producing a sufficient potential depression below the anode voltage by means of space charge and by electrostatic means outside the beam.
2. The equations derived by Gill may be employed to give the potential distribution when a current density, uniform over an infinite plane area, is projected normally through a screen into the screen-to-anode space of a plane-parallel system. The solutions are valid provided that the current density does not exceed a limiting value determined by the screen voltage, the anode voltage and the S-A gap. If the limiting current density is not exceeded the electrons leaving the screen plane are all transported to the anode.
3. Above the critical current density current division must occur somewhere between the screen and anode—some electrons travel to the anode, others are reflected back to the screen. The assumption that this occurs at a virtual cathode does not at all accord with the facts as the calculated knee voltages are much too high, and the predicted enormous hysteresis loops are not obtained.
4. A considerable modification is obtained by supposing that the electrons are given transverse deflections at the grid and screen wires. It is supposed that current reflection occurs at a finite potential instead of at zero potential; on this basis Equation (3) (8.3) is arrived at. The knee voltages are then found to be in reasonable agreement with experiment, while the hysteresis loops are much smaller than on the virtual cathode theory.
5. These results will again be modified because of thermionic velocities, multiple trajectories, etc., and especially because $\partial^2 V/\partial z^2$ is not zero over a beam of finite width.

Acknowledgments

The author's thanks are due to Mr. J. A. Jenkins, M.A., for helpful discussions on this subject, and to Mr. E. Y. Robinson, chief engineer of the Cosmos Manufacturing Co., Ltd., for permission to publish this article.

Supplementary Note

Equation (3) (8.3) has been put forward on the simplest hypothesis and should only be regarded as a first approximation. It should be emphasised, however, that an exact solution is calculable for any given distribution-in-angle of the current projected into the screen and anode space. In order to carry out the calculation it is preferable to expand the distribution function in powers of $\sin\theta_1$ and then to integrate to find the space charge density, as a function of V in both the screen to potential minimum space, and in the potential minimum to anode space. A first integration with respect to V will give dV/dx and a second integration, which is usually required to be numerical, will give x as a function of V.

The particular case in which the distribution plotted against $\sin\theta_1$ is flat-topped from $-\sin\theta$ to $+\sin\theta$ is the simplest. After calculation this yields as a closely true equation for the characteristic:

$$I = \frac{(1 + 1.6v_m)(1 - v_m)^{1/2} + (v_T - 1.1v_m)(v_T - v_m)^{1/2}}{\sqrt{2J_T - J_A}} + \frac{(v_2 + 1.6v_m)(v_2 - v_m)^{1/2}}{\sqrt{J_A}}$$

where $v_T = \sin\theta$ and $J_A = \frac{v_m}{v_T} . J_T$

Bibliography

[1] Jonker, *Wireless Engineer*, June, 1939, p. 174, July, 1939, p. 344.
[2] Harries, Brit. Spec. 380,429/1931.
[3] Harries, Brit. Spec. 385,968/1931.
[4] Harries, *Wireless Engineer*, April, 1936, pp. 190-199.
[5] Harries, *Wireless World*, Aug., 1935, p. 105.
[6] Shoenberg, Bull, Rodda; Brit. Spec., 423,932/1933.
[7] Bull, Keyston; Brit. Spec. 441,849/1934.
[8] Warren, *G.E.C. Journal*, 1937, p. 190.
[9] Shortley & Weller, *J. App. Physics*, May, 1938, Vol. 9, No. 5, p. 334.
[10] L. F. Richardson, *Phil. Mag.*, 1908, 15, p. 237.
[11] Kleynen, *Philips Technical Review*, Nov. 1937, pp. 338-345.
[12] Fortescue & Farnsworth, *Proc. A.I.E.E.*, 1913, 32, p. 757.
[13] Gabor, *Nature*, 1937, 130, p. 373.
[14] Langmuir, *Nature*, 1937, 139, p. 1066.
[15] Gill, *Phil. Mag.*, May, 1925, 49, pp. 993-1005.
[16] Bricout, *Comptes Rendus*, 1926, 183, p. 1269.
[17] Calpine, *Wireless Eng.*, Sept., 1936, 13, p. 473.
[18] Plato, Kleen, Rothe, *Zeits. für Physik*, 1936, Vol. 101, p. 509.
[19] Kleen, Rothe, *Zeits. fur Physik*, 1937, Vol. 104, p. 711.
[20] Salzberg, Haeff, *R.C.A. Rev.*, Vol. 2, No. 3, Jan., 1938, pp. 336-374.
[21] Fay, Samuel, Shockley; *Bell System Technical Journal*, 1938, Vol. 17, p. 49.
[22] Crank, Hartree, Sloane, Ingham, *Proc. Phy. Soc.*, 1939, Vol. 51, p. 952.
[23] Tonks, *Phys. Rev.*, Oct., 1927, pp. 501-511.
[24] Harries, *Electronic Engineering*, Jan., 1942, p. 586.
[25] Strutt & Van der Ziel, *Physica*, Oct., 1939, No. 9. p. 977.
[26] Below, *Zeits. für Fernmeldetechnik*, 1928, Vol. 9.
[27] Harries, Rodda, *Wireless Eng.*, June, 1936, 13, p. 315.
[28] Rodda, *Science Forum*, June, 1943.
[29] Gabor, *Nature*, Dec. 5, 1942, p. 650.
[30] Davisson & Calbick, *Phys. Rev.*, 38, 1931, p. 585,
[31] Davisson & Calbick, *Phys. Rev.*, 42, 1932, p. 580.
[32] Lenard, *Ann. d. Phys.*, 40, 1913, pp. 393, 424.
[33] Klemperer, "Electron Optics," p. 99.

A New Type of Oscillating Crystal

(*Concluded from p.* 648.)

substance is of the order of ten times the piezo-electric activity of quartz. The crystal in Fig. 1 was cleaved, normal to the principal axis, leaving a piece about 2 mm. long. This was found to resonate at the same frequency as before, indicating that there is no longitudinal compression or torsional vibration. On filing to the shape and dimensions in Fig. 2, the frequency of resonance became 340 kc/s. and then as Fig. 3 it became 486 kc/s. These figures agreed (within 5 per cent.) with a law:

$$f = \frac{1{,}760}{\sqrt{A}}$$

where f is the frequency in kc/s., and A is the cross-sectional area in sq. mm. This would seem to indicate that the vibration is a simple expansion and contraction about the axis.

The indicated temperature-coefficient is -426 parts in one million per $+1^\circ$ C. As this value is more than 200 times the value usually permitted in medium precision quartz, it will be seen that the crystal is quite unsuitable as a frequency stabilising element. While it is possible that a slant-cut crystal might have a zero coefficient, the angle of cutting would need to be very precise in order to obtain a good balance. Further experiments on lithium potassium tartrate crystals indicated that ageing effects are likely to be small, and that the substance is stable at all temperatures likely to be met with in normal apparatus in any part of the world. Breathing upon the crystal damps the oscillations, as with quartz, and it recovers as soon as the moisture has evaporated. While these crystals appear to be useless as frequency stabilising elements the ease with which they can be prepared will be of interest to amateurs. Such crystals might be used as thermometers in a suitable holder, and might also be useful as a stable substitute for Rochelle salt.

The author's thanks is expressed to a colleague, Mr. W. S. Mortley, who carried out the necessary electrical investigation on the crystals.

BOOK REVIEW

Electronic Equipment and Accessories

R. C. Walker. (George Newnes, Ltd., 1945. 25s. net.) 394 + xxxiv pp., 343 figs.

The sub-title to this book reads " A Concise Introduction to the Principles of Electronics and their Applications in Industry " and is a very fair indication of the scope of the book. In fifteen chapters the author describes what must be almost the whole gamut of electronic equipment. It is pleasing to note that electronic methods of performing tasks are not described or are only just mentioned when a mechanical method is better or more common. Readers must surely agree with the words of the Preface: "When a simple mechanical contrivance will meet the requirements, the novelty of an electronic device will be no recommendation for its adoption."

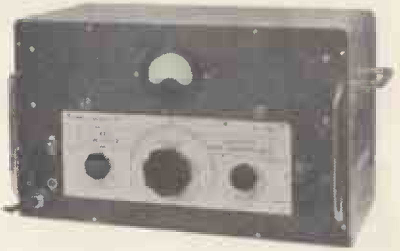
Starting with five chapters on thermionic valves, both vacuum and gas-filled, and describing their characteristics and applications, the book proceeds to photo-electric cells and their uses (three chapters); cathode-ray tubes (two chapters); miscellaneous electronic devices—neon lamps, barretters, etc.—(one chapter); small switchgear including an excellent section on relays (one long chapter); and three further chapters on delayed action devices, impulse counting, and miscellaneous circuit accessories. It concludes with a mathematical appendix containing some useful derivations of equations. Points which the reviewer would like to have seen included are a description of the very common Yaxley and Oak type switches—only a brief mention is given—as they are so widely used in electronic equipment and can perform a wide range of switching; a mention of the Burgess snap-action micro switch and an account under Impulse Counting of the scale-of-two " flip-flop " circuits for high-speed counting.

The book is intended for the use of readers familiar with the elements of electricity and magnetism but who are not specialists in electronics, *i.e.*, mechanics, practical engineers, students and the like. On the whole, the book is very suitable for such readers but in places tends to take for granted a higher standard of physical or electrical learning. For example, of what use is the mention, in the section on secondary emission valves, of the work function of a metal? The average reader of the classes mentioned above will not comprehend this—work function is not covered by the elements of electricity and magnetism.

Many photographs, line drawings and circuit diagrams contribute largely to the value of this book, but it is a pity that the author has not used symbols and abbreviations conforming to the usual standards. At random may be quoted the use of kc. for kc/s., ma for mA, μf for μF, and the indiscriminate use of ω and Ω for the ohms sign, sometimes both in the same diagram. Fig. 41 has 10ω where is obviously meant 10Ω (ohms), and Fig. 72, 2Ω for $2M\Omega$ (megohms). This is likely to be confusing to those not too well versed in the subject. Certain inconsistencies in the diagrams are annoying at times. Why show an envelope round ordinary valves but not round neons? Why are gas-filled valves sometimes shown with shading to represent gas and sometimes not? Why are some diagrams carefully labelled C_1, C_2, R_1, R_2, etc., but have no legends or mention in the text of their actual value?

But these small criticisms must not be allowed to detract from the general value of the book. As one of the first—the reviewer believes—British attempts to cover the field of electronic equipment and its uses from the electronic point of view and not from purely electrical or radio, it is to be highly recommended. Very likely it will become a popular text among all classes of users as a handy reference volume and will find its way into the library of many purely radio or purely electrical workers who want to know " how the other fellow does it."

E. D. HART.



NOTES FROM THE INDUSTRY

New Managing Director of the B.T.-H. Co.

Mr. H. Warren, M.Sc., chief of the Research Laboratory since 1929, has been appointed managing director of the B.T.-H. Co., Ltd. He is the author of numerous technical books and papers and is a member of the Government Radio Research Board, and many other scientific bodies.

Johnson Matthey & Co., Ltd.

Some little-known activities of Messrs. Johnson Matthey & Co. were referred to by the Chairman at the annual general meeting in June. These include fine wire for electrical resistances, fuses, instrument springs, and suspensions. The company has also drawn thousands of miles of fine seamless tubing for valves and capillary tubing for instruments. It has a range of fine automatic lathes, and has made some three hundred and fifty million instrument screws and other precision-turned parts in copper, brass and other non-ferrous metals.

New General Electric (U.S.) Research Laboratory

A new building for the General Electric Company's research laboratory, which will afford some 50 per cent. more space than present facilities provide, will be erected near Schenectady at a cost of $8,000,000.

Baekeland Memorial Lecture

On May 30, Mr. H. V. Potter, managing director of Bakelite Limited, gave the first of the Baekeland Memorial Lectures at the Royal Institution under the auspices of the Society of the Chemical Industry.

Baekeland gave the name "Bakelite" to a synthetic resin and also invented a gaslight printing paper employing silver chloride. This paper, which he named "Velox," has become known to photographers all over the world.

Electro-Deposited Paint

A new process for spray-coating objects with paint or similar material has been developed by the H. J. Ransberg Co., of Indianapolis. A field of 100,000 V D.C. is created and the article to be coated is passed through it and earthed by means of a conveyor belt.

The spray is charged and deposited on the earthed object. It is reported that a saving of 50 per cent in paint is obtained.

Photo-Electric Furnace Discharge Indicator

The principles of the photo-electric cell are well known and the applications of its properties are many and varied.

One unusual application recently tried out with complete success is the use of a photo-electric amplifier to give automatic indication when a charge travelling through a 100-kW roller hearth G.E.C. electric furnace arrives at a position near the door and is ready for being discharged.

The type of unit used is the G.E.C. M.D. photocell relay amplifier, incorporating a C.M.G. 8A photocell which controls the anode current of an Osram L63 valve in the anode circuit of which is a relay of the telephone type. A projector lamp unit mounted on the opposite side of the furnace provides the necessary light beam and so long as this beam illuminates the photocell the grid of the L.63 valve is maintained at a negative potential and the valve anode circuit is zero. As the charge passing through the furnace interrupts the beam, so the photocell control of the valve grid is removed, the anode current rises and operates the relay. This causes a warning buzzer or bell to sound and thus gives indication that the furnace is ready to be discharged.

The Institution of Electrical Engineers

Radio Section Committee

The following have been elected for the 1945-46 session:

Chairman:
A. H. Mumford, B.Sc.(Eng.).

Vice-chairman:
F. Smith, O.B.E.

Members of Committee:
G E Condliffe, B.Sc.
D. C. Espley, D.Eng.
C. E. Strong, B.A.I.

Electronic Stimulators

Addendum

An important and useful reference was omitted by the authors from the article "Electronic Stimulators," which was published in the July issue of this Journal. This is: "Electric Excitation of Nerve," by Katz (Oxford University Press).

CORRESPONDENCE

Dear Sir,—I have read with interest, but also with a sinking heart, the article entitled "An Electronic Musical Instrument," by Dr. W. Saraga, in your July issue.

The use, both theoretical and practical, of the thermionic valve as a generator of waveforms has been very thoroughly worked out since its inception. All musical instruments rely on the use of some such generator and the whole art of the design of musical instruments and the principles of playing thereof is entirely dependent on the way in which tone quality, attack and decay and volume of such generators can be controlled by the player. Both the composer and the performer are wholly concerned with how this control is carried out, and it is therefore essential that the designer of an electronic musical instrument should have a wide knowledge of both these interests—hence my dismay on reading Dr. Saraga's remark that, not being a musician, he depends on the co-operation of players and composers "for study of the musical features of his instrument."

He cannot expect to arouse much interest in the musical world by presenting a theoretical conception wrapped up, so to speak, in brown paper with his compliments and hope for the players and composers to unwrap it with eager expectation, leaving them with the delightful job of finding out how to use it.

Dr. Saraga's "instrument," while undoubtedly technically of much interest from the electronic engineers' point of view, presents no new feature over and above those known for many years, apart from his method of pitch control, and to my mind cannot, with justice, be described as an instrument. May I, therefore, plead with him, and with all others interested in this very fascinating subject, to realise that musicians have a background of wonderful achievement in design, conception and virtuosity and that they must be taken into account when any attempt is made to introduce anything new to them. They will not be slow to realise the possibilities of electronic instruments if only electronic engineers who wish to enter this field will prepare designs with their requirements in view.

Yours faithfully,
P. T. Hobson.

The MULLARD all-glass technique

By a complete departure from the conventional form of valve construction, Mullard have effectively reduced the losses due to H.F. resistance, inductance and capacity effects within the valve itself and in the leads coming from the electrodes. The all-glass technique makes use of an almost flat circular glass pressing for the base of the valve, into which short pins are sealed, the electrodes being welded directly to the pins. By thus reducing the length of the lead-out connections, considerably improved efficiency at the higher radio frequencies has been achieved.

A
DEVELOPMENT
OF THE
MULLARD
LABORATORIES

THE MULLARD WIRELESS SERVICE COMPANY LIMITED, CENTURY HOUSE, SHAFTESBURY AVENUE, W.C.2. (119C)

ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Electronic Device Indicates Peak Transient Voltages

An electronic "peak transient voltage indicator" employing the trigger characteristic of a gas-filled valve to indicate the presence of a transient voltage at a predetermined level is described. The value of the device, its origin and applications are discussed and circuit diagrams of it are given. Since control circuits and sensitive apparatus are used on alternating current it was considered advisable also to design an indicator to operate on A.C. A brief description of this instrument is given, the principle of operation being the same as for the D.C. instrument.

—*El. Wld.* 26/5/45, p. 80.*

Electronic Flame Cutter

A new system for guiding cutting torches on contour work on sheet steel is described. It employs plastic records which consist of a series of small light dots on a black background. As the record revolves, the light dots are registered by a photoelectric cell which operates the motors controlling the torches. A set of four record drums and photoelectric cells may be used to actuate the cutters, thus giving greater versatility. Such machines operating in fabrication plants have been tested under adverse conditions and are claimed to have been found most satisfactory.

—*Steel.* 28/5/45, p. 102.*

Electronic Motor Control

(B. J. Dalton)

A description of the working principles of electronic motor control is given with brief descriptions of typical applications, including the stopping or reversing of high inertia loads, control by voltage signals and the control of milling machines and material testing machines. In pointing out the advantages of this type of control the author quotes an instance in which during 10,000 hours of practically continuous operation on a wire enamelling machine the electronic control apparatus has required no maintenance attention of any kind.

—*G.E. Rev.* May, 1945, p. 12.*

400-Cycle Invertors for Military Aircraft

(C. P. Hayes and L. L. Ray)

A review is given of the authors' experiences in design and development of aircraft power supplies affording good wave shape, small voltage variations, freedom from radio interference and reliability over a wide range of operating conditions. Types of invertors discussed include mechanical vibrators, electronic invertors, dynamotors and motor alternators. A recent design which has been widely used in aircraft is described and illustrated by a circuit diagram and recommendations for future designs are also given.

—*El. Engg.* May, 1945, p. 233.*

Electronic Welding of Glass

(E. M. Guyer)

Localised heating of restricted areas that must be softened and flowed without destructive surface-boiling is accomplished by conduction. Novel high-frequency guns utilise auxiliary pin-point flames to lower glass resistance, provide a sharply defined gaseous conduction path from gun to glass, and facilitate close control of heating.

—*Electronics.* June, 1945, p. 92.

A Broadcast-Studio Control Console

(R. H. DeLany)

This paper gives a brief description of a studio console which has some unique features. The design is esthetic in appearance, is made for the comfort and convenience of the operator, and last, but not least, the equipment has complete accessibility for maintenance and repair. The vertical mixers increase the ease, accuracy and speed of operation making it possible to handle as many as six mixers simultaneously.

—*Proc. I.R.E.*, Oct., 1944, p. 600.

ELECTRON OPTICS

Historical Background of Electron Optics

(C. J Calbick)

Early methods of producing beams of charged particles are described. The effect upon these beams of magnetic and electric fields gives rise to the first laws of electron optics, and the author discusses early experiments and apparatus, leading up to the present-day oscillograph and electron microscope.

—*J. App. Phys.*, Oct., 1944, p. 685.*

MEASUREMENT

New Measuring Instrument

A description is given of an electronic-operated insulation resistance testing meter. It is mains operated and has a total range of 0.3 megohm to 50,000 megohms in three stages. The instrument may be used for a large number of insulation testing purposes including research upon the type of materials to be employed, correction of insulation design and bench testing of components. The principles of operation of the meter, which functions on 200/260 volts A.C., are given with reference to a circuit diagram.

—*Electn.* 15/6/45, p. 534.*

An Interval Timer for Arc Duration

This paper describes an electronic instrument developed for the purpose of measuring, in milliseconds, the time during which arcing exists when an electric circuit is opened. The instrument requires two input signals, one obtained from the arc voltage and the other from the circuit current, timing being initiated when the voltage signal appears and stopped when the current goes to zero. Circuit diagrams of power supply circuit and voltage and current signal circuits are given with examples to illustrate the usefulness of the instrument for timing both A.C. and D.C. arcs.

—*El. Engg.* May, 1945, p. 237.*

C.R. TUBES

Cathode-Ray Tubes and their Applications

(P. S. Christaldi)

After reviewing recent progress and developments in cathode-ray tubes, the author discusses high voltage intensifier tubes and an improved time-base circuit. The application of cathode-ray tubes to the testing of electrical circuits, insulation tests and tests on cables are discussed and it is pointed out that mechanical devices can be tested for vibration, balance and speed. Reference is also made to the study of optical problems by the cathode-ray spectrograph, and to non-destructive testing of metals.

—*Proc. I.R.E.* June, 1945, p. 373.

---

* Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester

---

The Scophony Electronic Stroboscope

THE Scophony Electronic Stroboscope Type G.E.604 provides a rapid and accurate means of measuring speeds of rotating or reciprocating mechanisms in the range of 600-14,400 r.p.m. and for the stroboscopic observation of rapidly moving objects in slow motion.

In general, the instrument consists of a grid-triggered neon lamp, the flashing rate of which is controlled by pulses from a variable frequency oscillator. The flash duration of the neon lamp is a few microseconds only, so that sufficiently sharp images are obtained even if the mechanism is moving at a high speed.

The unit is easily portable and may be operated from any 230-V 50-cycle A.C. power or lighting outlet. The speed reading appears in an illuminated window on the top of the instrument on one of two scales, the first for low and the second for high speeds, with ample overlap between the ranges, the range required being selected by a switch.

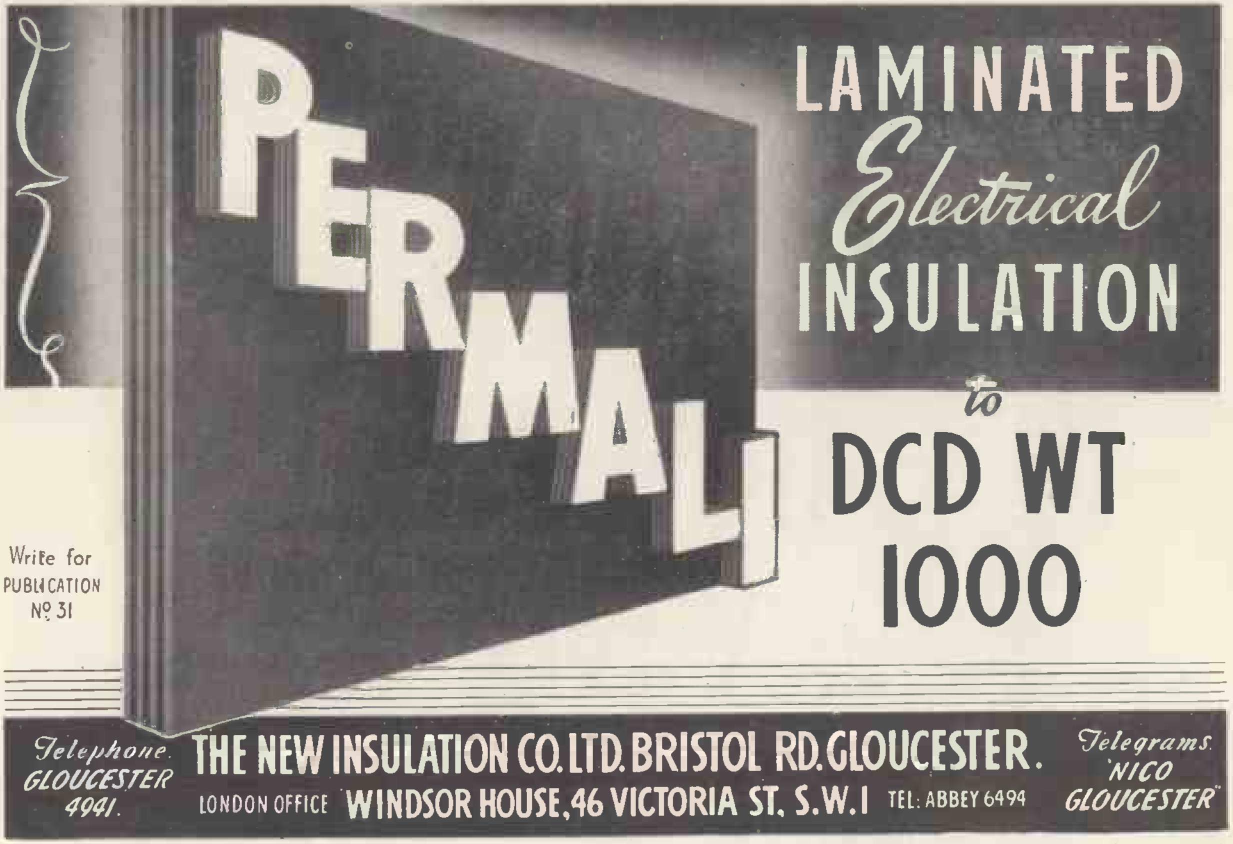
Weight : 15 lb.

Dimensions : 10½ in. × 7½ in. × 9½ in.

Power consumption : 40 watts.
Price £70.

The oscillator in the instrument can be linked to the mains frequency, in which case the light flashes will occur at a rate corresponding to multiples or sub-multiples of the mains frequency. This is particularly useful for observing synchronous mechanisms operating from the same A.C. mains as the stroboscope. It is also possible to link the flashing rate of the stroboscope to an electrical contactor on the mechanism under test through a specially provided bush marked "Cont." This arrangement has its uses if the speed of the mechanism under observation varies a great deal, in which case the stroboscope follows the speed variation of the mechanism automatically. For observing valve bounce, etc., of internal combustion engines this feature is of great value.

When standardised from A.C. time-controlled mains the accuracy is approximately 2 per cent. between the upper and lower limits marked on the calibrating controls. Accuracies far in excess of 2 per cent. can be realised by calibration over smaller ranges using the reed indicator, the accuracy being then determined by that of the mains frequency.




Thanks for the tip Bill! All my wireless needed was a Brimar Valve!

CLASSIFIED ANNOUNCEMENTS.

The charge for miscellaneous advertisements on this page is 12 words or less 4/- and 4d. for every additional word. Box numbers count as four words, plus 1/- extra for replies. Remittance should accompany advertisement. Cheques and P.O.'s payable to Hulton Press Ltd., 43 Shoe Lane, E.C.4. Press date—15th month for following issue.

FOR SALE

IN STOCK, Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc., Special Transformers quoted for.—University Radio, Ltd., 22, Lisle Street, London, W.C.2. Ger. 4447.

LOUDSPEAKERS

LOUDSPEAKERS—We carry on. Sinclair Speakers, 12, Pembroke Street, N.1.

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, N.1.

MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio Ltd., 22, Lisle Street, London, W.C.2. Ger. 4447.

WEBB'S Radio Map of the World enables you to locate any station heard. Size 40″ by 30″ 2 colour heavy Art Paper, 4/6, post 6d. Limited supply on Linen, 10/6, post 6d.—Webb's Radio, 14, Soho Street, London, W.1 Phone : GERrard 2089.

MORSE Practice Equipment for Class-room or Individual Tuition. Keys, Audio Oscillators for both battery or main operation. Webb's Radio, 14, Soho Street, London, W.1. Phone : GERrard 2089.

BE SURE AND WRITE NOW for our latest large Mail Order List. Included in the hundreds of bargains and " short-supply " lines available at once from stock are the following : Instrument type Cabinets in 18-gauge steel. Chassis panels, complete racks. Condensers, coils, volume controls, heavy duty chokes, etc. Send now for Mail Order List " E," 2½d. post paid. Waveband Radio Ltd., 63, Jermyn Street, London, S.W.1.

COIL WINDING. Vacuum/Pressure Impregnating. Godfrey Industries, Limited, Brundall, Norfolk. Telephone : 90.

THE TECHNICA CAMERA CO., 21, William IV Street, W.C.2, consulting photographic engineers to H.M. Government Departments, undertake the solving of photo-electric and other problems.

MECHANICAL ENGINEERS to the Electronic Industry. Precision and Optical Instruments of all types designed and constructed in collaboration with Electronic Engineers. Tecnaphot Ltd., Mile Lane, Coventry.

WINDING WIRE, SURPLUS ODDMENTS, 14 swg to 50 swg enamelled and/or silk/cotton, offered to Wireless and Electrical Retailers. Box 734, " Electronic Engineering."

TELE-RADIO (1943), LTD., for brand new godo quality components at manufacturers' list prices. Suppliers to professional constructors and amateurs who want only the best. Weston meters, 250 micro amps, centre zero reading, £3 5s.; 0-1 mA, £2 10s.; 0-500 micro amps, £3 ; 0-100 micro amps, £3 15s.; 0-50 micro amps, £4 10s. ; 1 mA instrument rectifiers, 12s. 6d. ; spot-on wire-wound precision resistors, plus or minus 0.05 per cent., 5s. 6d. each (up to 50,000 ohms only) ; single-pole 12-position switches, 3s. 6d. each ; 4-pole 3-way, 3s. 6d. each ; cathode-ray tubes, G.E.C., 1½ in., £2 15s. ; Cossor 23D, 2¾ in., £3 6s. ; Cossor 26D, 4½ in., £6 10s. ; Cossor GDT4B gas-filled triode, 24s. 4d. ; high-voltage rectifiers and condensers ; potentiometers carbon 4s. 6d. ; with switch, 6s. 6d. ; wire wound, 6s. 6d., all usual values ; crystals, 100 kc/s., 45s. (P.O. permit) ; Rothermel crystal pick-ups, £3 13s. 6d. and £3 18s. 9d. (high fidelity Red Label 10s. extra) ; Celestion and Vitavox speakers ; 0.0005 2-gang condensers, ceramic insulation, with S.M. drive, 16s. 6d. ; wave-change switches, variable condensers and trimmers, etc. ; comprehensive stocks of British and American valves ; steel racks, chassis, panels and cabinets, any specification (callers only) ; postage and packing extra on all goods.—Tele-Radio (1943), Ltd., 177a, Edgware Road, London, W.2. Tel. Pad. 6116.

BERRY'S (SHORT WAVE), LTD., for quality Radio and Electronic Products including :—C.R. Tubes 1½ in. 55/-, 2¾ in. £3 6s., 4½ in. £6 12s. P. Coils 2s. 3d. and 2s. 6d. I.F.'s 7s. 6d. each. Crystal pick-ups 73s. 6d. and 78s. 8d. ; Crystal mikehead 75s. ; Muirhead 9-1 S.M. dial with driving head 35s., 5-1, 25s. ; S.M. drive escutcheon and glass 8s. 6d. Metal cabinets, panels and chassis 39s. 6d. and 63s. Speakers 2½ in. 27s., 3 in. 30s., also 5 in. to 12 in. Jacks and Jackplugs 2s. 6d. each. Vortexion 20 w. Amplifier for mains or battery £19 13s. 9d. Ceramic trimmers, condensers, stand-offs, formers, valve bases, etc. Fuseholders, Single 2s. 6d., Twin 3s. 6d. Volume controls 4s. 3d., with switch 5s. 9d. Polystyrene rod, tube or sheet. Send S.A.E. for complete List " E " to Berry's (Short Wave), Ltd., 25, High Holborn, London, W.C.1. Tel. : HOLborn 6231.

SITUATIONS VACANT

A.M.I.E.E., City and Guilds, etc., on "NO PASS - NO FEE " terms. Over 95% Successes. For full details of modern courses in all branches of Electrical Technology send for our 112-page handbook—FREE and post-free. B.I.E.T., (Dept. 337B), 17 Stratford Place London, W.1.

RADIO VALVE ENGINEER required. University trained with at least 10 years' experience of valve development and manufacture. Must possess initiative to follow a new type through to the shop and ensure economical manufacture. Appointment when relevant restrictions are withdrawn. Write in confidence to Box 7192, A.K. Advg., 212a, Shaftesbury Avenue, London, W.C.2.

CATHODE-RAY TUBE ENGINEER required. University trained with at least 10 years' experience of Cathode-Ray Tube development and manufacture. Must possess initiative to follow a new type through to the shop and ensure economical manufacture. Appointment will be made after relevant restrictions are withdrawn. Write in confidence to Box 7195, A.K. Advg., 212a, Shaftesbury Avenue, London, W.C.2.

BERRY'S (SHORT WAVE), LTD., have vacancies for Class A ex-servicemen experienced in (a) Communication receivers, (b) Transmitters, (c) Transmitting valves. Full details of experience and past positions, to 25, High Holborn, London, W.C.1.

DEVELOPMENT ENGINEER required by established radio and communications component manufacturers. Must have had at least 4 years' experience in the design and production of paper and mica dielectric capacitors. Education up to Inter-B.Sc. standard. Salary £350 or more according to experience and ability. Box No. 746, " Electronic Engineering."

DEVELOPMENT ENGINEER required by established radio and communications component manufacturers. Must have had 4-5 years' experience in the design and production of radio receiving and low-power transmitting apparatus, and associated test apparatus. Education at least comparable to Inter-B.Sc. standard. Salary £350 or more according to experience and ability. Box No. 747, " Electronic Engineering."

REDIFFUSION, LTD., will have vacancies for qualified radio engineers and draughtsmen. Permanent and progressive positions. Appointments will be made when present restrictions are relaxed. Apply 11D, Lower Regent Street, S.W.1.

ELECTRICAL TESTING apparatus and equipment. Manager wanted for small high-quality design and production plant, handling quantities up to 20 of a diverse range of test gear, which includes R.F. ; not in London area. Knowledge of theory and practical ability to produce are essentials. Qualified engineer preferred. Excellent prospects for advancement in important business organisation for effective, industrious, youngish man of right character. Write stating salary required to Box 7496, A.K. Advtg., 212a, Shaftesbury Avenue, W.C.2.

SITUATION WANTED

SALES ENGINEER, with extensive experience and connections, desires contact (view Sales Managership or other responsible post) manufacturer entering or expanding industrial electronics. Box 748, " Electronic Engineering."

WANTED

WE OFFER cash for good modern Communication and all-wave Receivers.—A.C.S. Radio, 44, Widmore Road, Bromley.

WANTED. January, February, March, April, May, June, 1945, issues of " Electronic Engineering." State price. Rowlands, The Laurels, Hawarden, Chester.

TELEVISION RESEARCH ENGINEER REQUIRED

EXPERIENCE ESSENTIAL

Box No. 745, " Electronic Engineering."

Improved Battery Charging
CLIPS

Well made of steel, double ridged for strength. Teeth on three sides of lower jaw and special design of upper jaw ensure firm grip and good contact.

Wingard products are always equal to the job they have to do. For our own sakes—as well as yours—they bear our name, because the reputation of the maker is, in the last analysis, the best guarantee of the product.

Wingard (M.A.) LTD.

CHURCH ROAD · HENDON · LONDON · N.W.4

MELTON METALLURGICAL LABORATORIES LTD.

AVOID WHISKERS!

You cannot afford to take chances by using a soldering flux that will eventually cause corrosion on your electrical connections.

MELTON Non-Corrosive Liquid Flux, grade N21 (A.I.D. approved) conforms with Air Ministry Specification D.T.D. 599 and may be used with confidence on all electrical and other work, where corrosion would be injurious.

Sold in 4 oz., ½ pt., 1pt., tins and in bulk.

IPSWICH ROAD
TRADING ESTATE
SLOUGH, BUCKS.

Phone: Slough 20992

WE STILL HAVE THIS LITTLE FELLOW TO SETTLE before our production is entirely free from Government control.

Until then we are reserving any spare productive capacity for our old customers.

RELIANCE

Manufacturing Co. (Southwark) Ltd.,
Sutherland Road, Higham Hill, Walthamstow, E. 17
Telephone: Larkswood 3245.

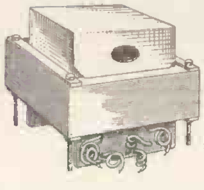
P. X. FOX, LTD.,

HORSFORTH, YORKSHIRE

FOR STANDARD OR SPECIAL TYPES OF—

TOROIDAL POTENTIOMETERS

POWER TRANSFORMERS
for ALL P.A. EQUIPMENT



Type K450H (*as illustrated*) 50/-
Recommended for 6L6 and 807 valves.
450-0-450v. 250ma., 5v. 3a. and two 6.3v. 4a. C.T.

OUTPUT AND INTERVALVE TRANSFORMERS

Our OP12K. Multi-ratio, 50-watt 52/-
Type K1V3. Intervalve. Split P. & S. 40/-
Above types supplied in steel cases with panels.

Write for further details and ask for LIST 55/EE.

RADIO INSTRUMENT Co.
294 Broadway, Bexleyheath, Kent
Telephone: Bexleyheath 3021

Dainite
MOULDED RUBBER PARTS

As soon as conditions permit we hope to offer our usual "DAINITE" Service for Moulded Rubber Parts. In the meantime, enquiries for permitted essential lines will receive every attention.

THE HARBORO' RUBBER CO., LTD., MARKET HARBOROUGH.

BRAY CERAMIC INSULATORS
for L.F. and H.F. Components: also capacitor dielectrics

made by
GEO. BRAY & CO., LTD. LEEDS, 2
Established 1863 Phone Leeds 20981

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors and Publishers, Hulton Press, Ltd., 43-44, Shoe Lane London, E.C.4.
Sole Agents for Australia and New Zealand: Gordon and Gotch (A/sia), Ltd. South Africa: Central News Agency, Ltd.
Registered for Transmission by Canadian Magazine Post.