PHILIPS

# LABORATORY REPORT

ELECTRON TUBES
SEMICONDUCTORS
COMPONENTS
MATERIALS

Group : The Mullard Radio Valve Co. Ltd.,
Applications Research Laboratory
Transmitting Valve Section.
Date : 26.1.1960.
Author : F. Dittrich.
Title : A high-C oscillator, suitable for dielectric heating.
Rep.No.: T 817.
Ref.No.: GII 6001.

ISSUED BY PHILIPS ELECTRON TUBE DIVISION
INDUSTRIAL COMPONENTS AND MATERIALS DIVISION

N.V. PHILIPS' GLOEILAMPENFABRIEKEN
*Electronic Market Development Dept.*

**FOR YOUR PERSONAL INFORMATION**

Group : The Mullard Radio Valve Co. Ltd.,
Applications Research Laboratory
Transmitting Valve Section.
Date : 26.1.1960.
Author : F. Dittrich.
Title : A high-C oscillator, suitable for
dielectric heating.
Rep.No.: T 817.
Ref.No.: GII 6001.

c

THE MULLARD RADIO VALVE CO. LTD.

GII 6001

APPLICATIONS RESEARCH LABORATORY

TRANSMITTING VALVE SECTION

D.V.T. Report No: T817

Subject: Industrial Heating

Notebook No. 2972A

Date: 26.1.60

# A HIGH-C OSCILLATOR, SUITABLE FOR DIELECTRIC HEATING.

## 1. INTRODUCTION.

A circuit unit designed to provide a measure of frequency stability in power oscillators was described in D.V.T. Report No. T791.

A laminated tank circuit of this kind has been incorporated in a form of "plastic welder" apparatus in order to assess the efficiency and frequency shift of such an oscillator under field conditions of usage. The apparatus is described herein.

No attempt was made at this stage to suppress radiation of energy at fundamental or harmonic frequencies.

## 2. SPECIFICATIONS.

### 2.1. Drift.

The drift during any one operation should not exceed the proposed ±0.6% of 27.12 Mc/s, i.e. a total of 320 kc/s.

A change of electrode size and shape or of dielectric material should not pull the oscillator frequency out of the prescribed band.

### 2.2. Power.

It should be possible to weld an area of 5 square inches of .016" pvc sheet in 3 seconds or less, irrespective of the shape this area takes. With a minimum required power density of 100W/sq.in. at least 600W should be available in the load circuit at a $\eta_{ld} > 50\%$.

Contd/...

## 3. VALVE CONDITIONS.

As welding operations are of the duration of a few seconds at the most, a duty ratio rating may be applied, increasing the input by current increase rather than. voltage and thereby finding a good compromise between valve and circuit efficiency.

The mean input during a 3 second weld would then be derived from:

$$\begin{aligned} V_a &= 2.5\text{kV} \\ P_{in} &= 1250\text{W} \\ I_a &= 500\text{mA} \\ P_{out} &= 940\text{W} \\ \eta_a &= 75\% \end{aligned}$$

giving the instantaneous values

$$V_{min} = 300\text{V} \qquad V_{pk} = 2200\text{V}$$

and therefore:

$$Q_1 = \frac{1560^2}{940 \times 11} = \underline{\underline{235}}$$

$$i_{1rms} = \frac{P_{out}}{v_{1rms}} = \frac{940}{1560} = 0.6\text{A}$$

$$i_c = Q_1 \times i_{1rms} = 235 \times 0.6 = \underline{\underline{141\text{A}}}$$

making the circuit losses

$$P_c = 141^2 \times 0.01 = \underline{\underline{200\text{W}}}$$

and the load power:

$$\begin{aligned} P_{out} &= 940\text{W} \\ -\ P_{dr} &= 30\text{W} \\ -\ P_c &= \underline{200\text{W}} \\ P_{ld} &= \underline{\underline{710\text{W}}} \\ \eta_{ld} &= \underline{\underline{56\%}} \end{aligned}$$

Contd/...

## 4. TANK CIRCUIT.

At 27 Mc/s a tank capacity of 550pF has in previous experiments at similar power levels proved to be a good compromise between the conflicting requirements of high stability and avoidance of undue circuit losses.

So that for

$$f_o = 27.12 \text{ Mc/s}$$

$$C_T = 550 \text{ pF}$$

$$L_T = .063 \mu\text{Hy}$$

$$V_{a\ max} = 3\text{kV}$$

the dimensions for the laminated circuit, using the design procedure outlined in D.V.T. Report No.T791, will be:

Number of laminae ... 20

(With 5A circulating current per lamina this should be 28, but in order to reduce the size of equipment it was decided to accept the resulting small increase in circuit losses.)

| | | | |
|---|---|---|---|
| Dielectric spacing | d | = | 7mm |
| Inductive cut out diameter | D | = | 112mm ($4\frac{1}{2}$") |
| Width of lamina | B | = | 127mm (5") |
| Length of lamina | A | = | 368mm (14.5") |

Thickness of lam. material........ 16s.w.g. Al.

## 5. LOAD CIRCUIT.

Inductive load coupling was chosen, as this allows the r.f. potential across the work piece to be kept less dependent on the maximum possible r.f. potential across the tank circuit.

The load circuit then consisted of a single turn inductance and a capacitance formed by the electrode, platen and the lossy dielectric.

As such an arrangement is frequency conscious the load frequency may, according to the volume and dielectric constant of the work piece, be below, at or above oscillator frequency. In the interests of economic equipment utilisation it is however advantageous to take the load circuit through the generator resonance during the time of weld.

Contd/...

Off-resonance welds are of course possible if the welding time is increased. In either case the necessary r.f. potential at the work piece may be adjusted by varying the degree of coupling and/or the d.c. supply to the oscillator valve.

## 6. CONSTRUCTION.

The self contained equipment is housed in a 4 ft. standard rack and for the purposes of description may be divided into 3 parts. (Figures 1 and 3)

### 6.1. Power pack. (Figures 2 and 3)

This is a conventional full wave bridge rectifier followed by a choke input filter. The d.c. potential may be set by means of a variac in the primary of the h.t. transformer.

The rectifier valves are 4 RG1-240A and will be capable of giving the required output of 2.5kV.x 500mA continuously, or with an averaging time of 15 seconds twice the current may be drawn for up to $7\frac{1}{2}$ seconds.

In order to safeguard both rectifiers and oscillator valve a current operated cut out of pre-determinable sensitivity is included.

The duration of the work cycle is governed by a self re-setting timer, facilitating continuously variable timing from .1 to 10 seconds. This timer will come into operation when the microswitch, linked to the foot control, is operated. For experimental purposes a set of push buttons has also been provided, which are operative when $S_2$ is in position II, taking the timer out of circuit.

### 6.2. Oscillator Chassis. (Figures 2 and 3)

The laminated circuit with valve and associated decoupling elements are mounted together with the filament transformer for the TY3-250 on a vertically moveable sub-chassis, the position of which in relation to the load coil may be adjusted by means of a turnsindicating dial and threaded spindle. A 12W Philips fan also mounted on the sub-chassis provides air cooling for the oscillator valve.

Whereas in practice all of the sub-chassis would be enclosed in a shielding box, coupling the tank circuit to the load through a faraday screen, this was, for demonstration purposes omitted in the described model. If screening is used, this should be spaced at least 2" all round from the tank circuit.

Contd/...

### 6.3. Load circuit and Press head. (Figures 2 and 3)

The top panel carries the load circuit, platen support, press head and pressure transfer mechanism connecting the press head to the foot pedal rods. Instruments and auxiliary switches are also mounted on this panel. The maximum pressure available is 150 lbs.

## 7. RESULTS.

### 7.1. Cold frequency checks.

### 7.1.1. Tank circuit.

Mounted on the chassis with valve and all components connected the tank circuit resonated at 27.8 Mc/s. The correct resonance of 27.12 Mc/s was obtained by mounting and adjusting 2 auxiliary trimming plates at the capacitive end of the laminated circuit.

### 7.1.2. Load circuit.

The load circuit inductance is so dimensioned as to resonate at 28 Mc/s with the load capacity formed by the 5 sq. in. electrode and 2 thicknesses of .016" pvc sheet.

### 7.2. Operational Tests.

### 7.2.1. Dummy load measurement.

A Termaline Wattmeter was matched to the electrode and with the input figures as suggested in (3) the following readings were taken:

$V_a$ = 2.5kV
$I_a$ = 500mA
$P_{in}$ = 1250W
$P_{ld}$ = 650W
$\eta_{ld}$ = 52%
$R_g$ : 230V/25W lamp
$I_g$ = 110mA.

Contd/...

### 7.2.2. "Through resonance" welds.

With the load circuit set up as described under (7.1.2.) 2 layers of .016" pvc sheet could be satisfactorily fused together, as detailed in the following table:

Table 1.

| Area of weld | Duration of weld | Duration of max $P_{in}$ | $I_a$ max (on tune) | $I_a$ min (off tune) | $I_a$ mean over stated welding time. |
|---|---|---|---|---|---|
| ins. | seconds | seconds | mA | mA | mA |
| 1 x 4 | 3 | $\leq .5$ | 900 | 300 | 400 |
| .125 x 36 | 4 | $\leq .5$ | 900 | 400 | 465 |
| 1 x 5 | 3 | $\leq .5$ | 950 | 400 | 490 |
| 2 x 3 | 4 | $\leq .5$ | 950 | 400 | 470 |

The results listed were repeatable for any number of welds at a duty ratio $\leq .5$. Although peak $I_a$ figures are rather high they are of such short duration that the mean anode current is always near the target of 500mA.

The drift during all above operations was

$$\Delta f \leq 100 \text{ kc/s.}$$

The maximum shift, when changing electrodes was approximately 50 kc/s.

### 7.2.3. "Off tune" welds.

When the area of weld was so small ($\frac{1}{2}$" - 4") that the load circuit was at all times off resonance, welds could still be effected by tighter coupling and lengthening of welding time. The input during the work cycle is then practically constant and $I_a$ = 500mA should not be exceeded.

The resulting frequency drift during these operations is

$$\Delta f = 60 \text{ kc/s.}$$

### 7.2.4. Open and short circuit test.

Frequency deviation readings were taken with the welding electrode both open and short circuited with a resultant shift of

$$\Delta f = 20 \text{ kc/s.}$$

Contd/...

## 8. CONCLUSION.

With a maximum deviation of 100 kc/s during any one weld stability conditions for the 27 Mc/s band have been satisfied.

A change of welding electrode as well as open and short circuit conditions produce so little disturbance that the maximum resultant deviation is still well within the proposed limits.

Sufficient power was available at the work electrode to effect welds up to 5 sq. in. in 3 seconds.

If a shortening of the welding time were desired, $P_{in}$ would have to be increased necessitating the use of a bigger oscillator valve such as the TY5-500.

A further measure, also reducing the welding time would be to increase the foot pressure to 2 - 3 times the stated value.

In order to bring electrodes smaller than those listed in Table 1 into resonance with the generator a variable capacitor could be switched in parallel to the load circuit.

SIGNED:
F. DITTRICH.

for L. BOUNDS
DEPARTMENTAL HEAD

Copies to Messrs:
Bellenger
Britton
Chanter
Haynes
Kleiner
Rodenhuis (E)
Verstraten
Wilson (M.O. Ltd.)

FD/MAT.

# APPENDIX TO D.V.T. REPORT NO. T817.

## 1. INTRODUCTION.

Although welds were successful with the load circuit set for frequencies other than that of the generator, it appeared desirable to include, as already suggested, a compensating capacitor in parallel with the working electrode, facilitating the matching of the load for a greater variety of electrode sizes and material thicknesses.

## 2. MODIFICATION.

As the frequency setting of the load circuit is achieved by a variable capacitor in parallel with the load (figure 4a), it is obvious that for the largest possible capacity variation at a given frequency (27.12 Mc/s) the resultant circuit inductance should be small. The original load coupling coil consisting of one 4" diameter turn of $\frac{3}{8}$" o.d. copper tube was replaced by a 3" wide copper band. (With more space available this could be even wider). Owing to relative positions of the existing tank circuit and working surface the shape of this copper band appears somewhat complicated(figure 4b). This need not be so however, if the layout is suitably arranged ab initio. (figure 4c). The compensating capacitor was mounted just outside the front panel, under the platen and its "live" side connected by a 1" copper strap to the "live" side of the load circuit. It is a conventional transmitting type, variable from 30 to 150 pF and capable of withstanding 2kV pk. As it is shunted across part of the total load circuit inductance only, this dielectric spacing is sufficient in the present instance.

## 3. RESULTS.

For the results listed, the compensating capacitor was so far advanced that the resonant frequency of the load circuit (for a given p.v.c. sheet thickness and electrode size) would be about 0.5 Mc/s on the high side of the generator frequency at the beginning, and go through resonance during the welding operation.

Due to the considerable shortening of the welding times only the peak current values could be read.

Contd/...

Table 1.

| Material thickness Ins. | Area of weld Ins. | Duration of weld Seconds | $I_a$ max (mA) | Duration of $I_a$ max Seconds | $\Delta f$ max kc/s |
|---|---|---|---|---|---|
| 3 x .006* | 1 x 3 | 1.5 | 850 | 1 | 130 |
| 2 x .006* | $\frac{1}{2}$ x 5 | .8 | 800 | .8 | 120 |
| 2 x .006* | $\frac{1}{8}$ x 8 | .3 | 800 | .3 | 90 |
| 2 x .016 | $\frac{1}{8}$ x 8 | .5 | 800 | .5 | 100 |
| 4 x .016 | $\frac{1}{8}$ x 8 | 2.0 | 800 | 1 | 100 |

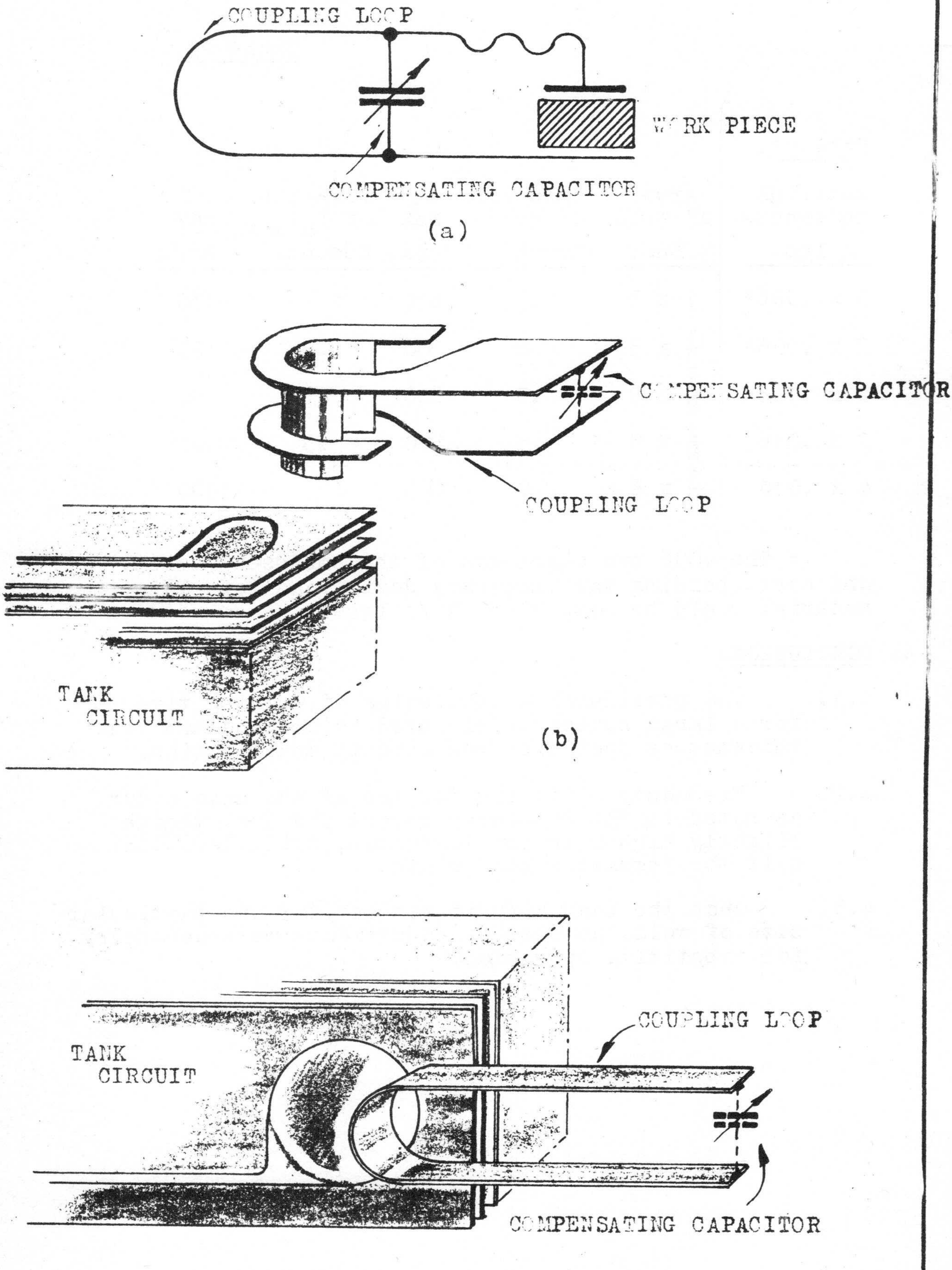
* The .006 pvc sheet was of the embossed variety and corresponding max frequency deviations for plain material would be some 20-30 kc/s less.

## 4. CONCLUSION.

4.1. The considerable shortening of welding time for a large number of electrode sizes and material thicknesses justifies the circuit modification.

4.2. Frequency drift figures are of the same order as noted in the preceding report and are, though slightly higher in two instances, still less than half the permitted band width.

4.3. Once the load circuit was set for one particular size of weld, no further adjustments were necessary for repetitive operation.



MODIFICATION TO LOAD CIRCUIT.


MULLARD
TRANSMITTING & MICROWAVE DIVISION
APPLICATIONS
RESEARCH LABORATORY
CIRCUIT DESIGN
Oscillator incorporating valve TY3-250 with the Mullard laminated tank circuit feeding electrodes for welding plastic sheet.
V 2.5 kV P 550 W
I 500 mA f 27.12 Mc/s
Frequency shift during weld—less than 100 kc/s.

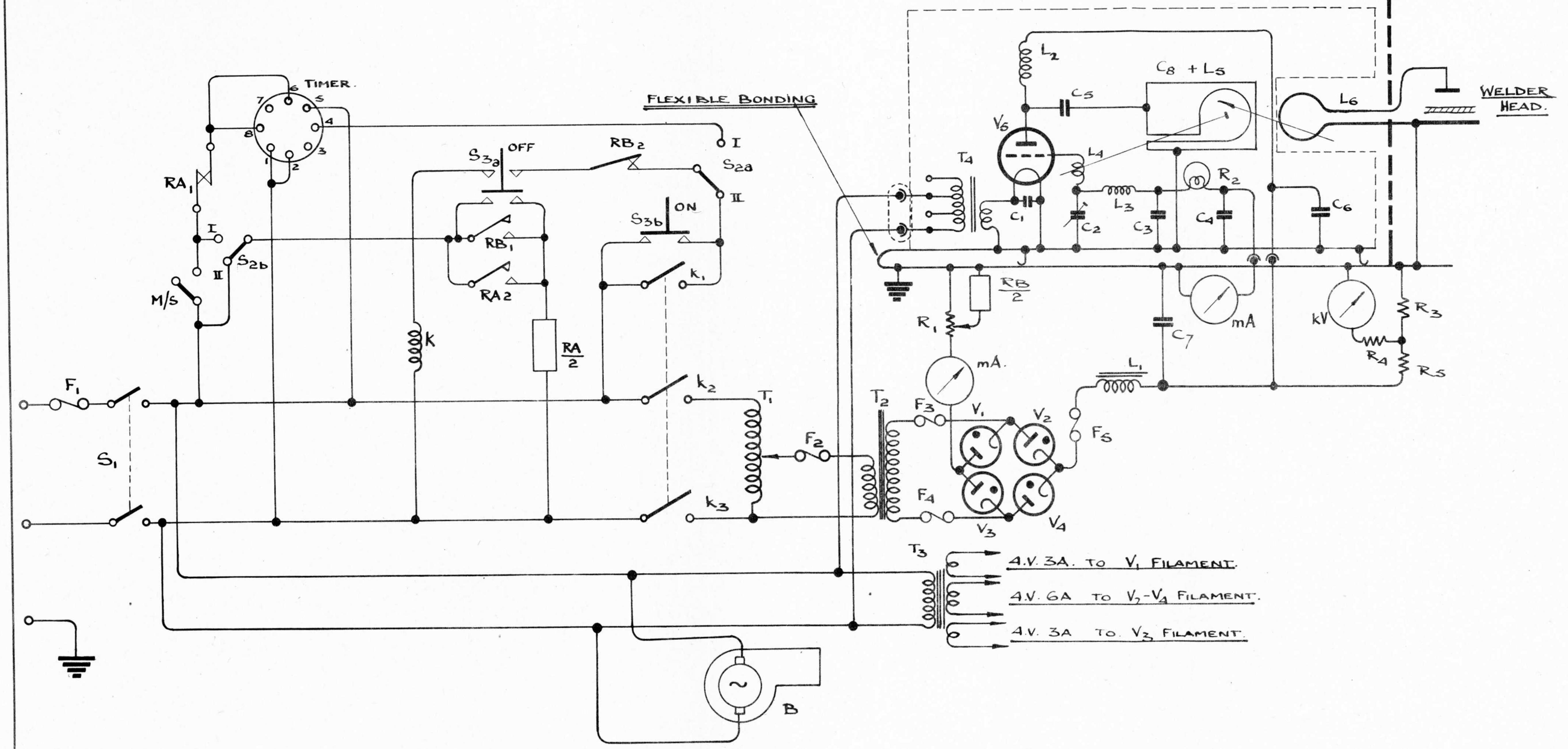
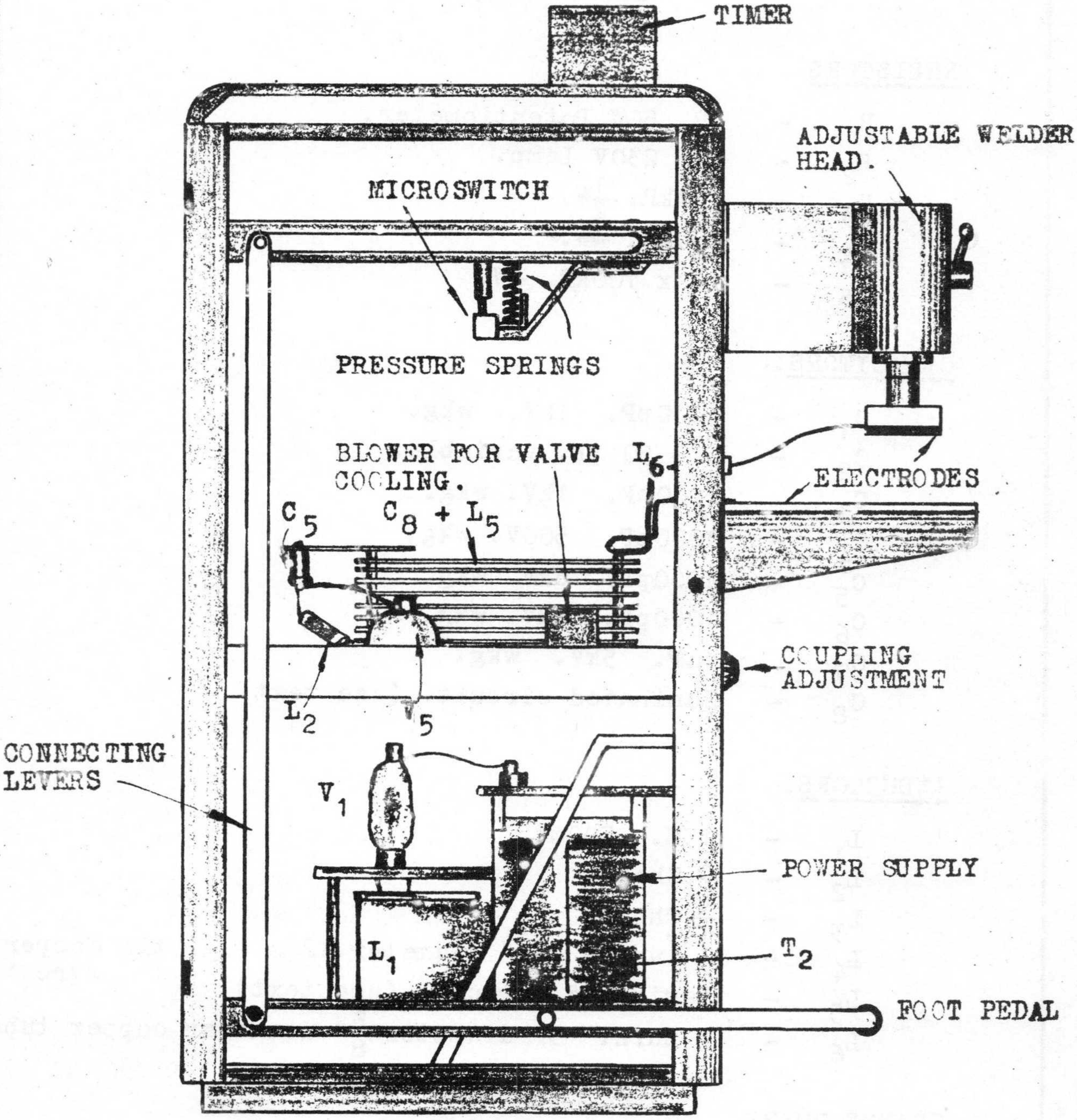


FIGURE. 2. CIRCUIT DIAGRAM – EXPERIMENTAL PLASTIC WELDER.



EXPERIMENTAL PLASTIC WELDER.

FIGURE 3.

## COMPONENT LIST

## PLASTIC WELDER

### RESISTORS

$R_1$ - 8Ω. 50W Potentiometer.
$R_2$ - 25W 230V Lamp.
$R_3$ - 100kΩ. $\frac{1}{2}$W.
$R_4$ - 250kΩ. $\frac{1}{2}$W.
$R_5$ - 14 x 100kΩ. $\frac{1}{2}$W.

### CAPACITORS.

$C_1$ - 1000pF. 1kV. wkg.
$C_2$ - 5 - 50 pF. variable.
$C_3$ - 1000pF. 1kV. wkg.
$C_4$ - 1000pF. 500V. wkg.
$C_5$ - 1000pF. 6kV. wkg.
$C_6$ - 1000pF. 6kV. wkg.
$C_7$ - 1μF. 5kV. wkg.
$C_8$ - Laminated circuit. (see text)

### INDUCTORS.

$L_1$ - 15H. 500mA.
$L_2$ - $\frac{\lambda}{4}$ Choke.
$L_3$ - $\frac{\lambda}{4}$ Choke.
$L_4$ - 2 turns. $3\frac{1}{2}$" diameter 12 s.w.g. tin copper wire.
$L_5$ - Laminated circuit. (see text)
$L_6$ - 1 turn. 3" diameter $\frac{3}{8}$" diameter copper tube.

### TRANSFORMERS.

$T_1$ - Variac. TYPE: 100L.

$T_2$ - 220V Primary
Secondary windings to give:-
3300V r.m.s. at 1.75 k.V.A.

$T_3$ - 220V Primary
Secondary windings to give:-
4.V. - 6A.
4.V. - 3A.
4.V. - 3A.

Contd/...

### TRANSFORMERS (contd.)

$T_4$ - 5 - 0 - 200 - 210 - 220 - 230 - 240V. Primary.
Secondary windings to give:-
5V - 14A.

### SWITCHES.

$S_1$ - 2 pole Stanton.
$S_2$ - 2 pole - 2 way toggle.
$S_3$ - Press button set.
M/S - Microswitch.
K - Klockner. MK II Air Brake 230V 50

### TIMER.

Chamberlain and Hookham.
Type P - 0.01 to 10 sec.

### RELAYS.

RA - Londex 220 v.a.c.
RB - Post Office type: 50Ω coil.

### FUSES.

$F_1$ - 15A.
$F_2$ - 10A.
$F_3$ - 14A.
$F_4$ - 1A.
$F_5$ - 1A.

### VALVES.

$V_1$ - RG1 - 240A.
$V_2$ - RG1 - 240A.
$V_3$ - RG1 - 240A.
$V_4$ - RG1 - 240A.
$V_5$ - TY2-250.

### BLOWER.

$B_1$ - Plannair Blower (Leatherhead)

Printed in Holland