INDUSTRIAL ELECTRONICS CIRCUITS

BY

R. KRETZMANN

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PREFACE

With the increasing application of electronic aids in nearly all branches of industry, there is a growing need for circuits which have been proved in practice, not only to serve the purposes of industrial engineers, but also to assist the technicians who are engaged in the development of electronic equipment. To help meet this need I decided to bring out the present volume as a sequel to my "Industrial Electronics Handbook", and the two books together form a continuous whole. References are made in this work to various sections of its companion.

Most of the circuits have been developed in the laboratory. For the sake of clarity, certain parts, such as stabilized power-packs, pre-heating devices for tubes, etc., have sometimes been left out of the circuit diagrams. These would be important in production equipment, and must not be overlooked if any of the circuits are adopted. The position with regard to patents should also be examined, and I would further like to point out that the mention of any particular apparatus, tubes, or other components, does not imply that they are now available.

The figures in square brackets, used in the text, refer to the bibliography at the end of the book.

Finally, I should like to express my thanks to Mr. D. J. Mitchell, M.A. (Cantab.) for preparing an excellent translation, Mr. H. P. White of Mullard Limited for scrutinizing the text and Mr. J. H. J. van Koppen of Philips, Eindhoven, for reading the proofs.

R. Kretzmann

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1. Photoelectrically Controlled Apparatus

Automatic Exposure Timer

For photographic printing work a photoelectric exposure timer can be usefully employed to obtain accurately matched prints. The circuit of such a device is shown in Fig. 1-1; the photocell *P* is arranged behind the negative and is movable, so that it can be brought behind the densiest parts, as required. Before the exposure is started, S_1 is open and S_2 closed, in which condition the right-hand triode of the E90CC is conducting and the left-hand triode is cut off. The printing process is commenced by opening S_2 and simultaneously closing S_1, so that *La* illuminates the photocell.

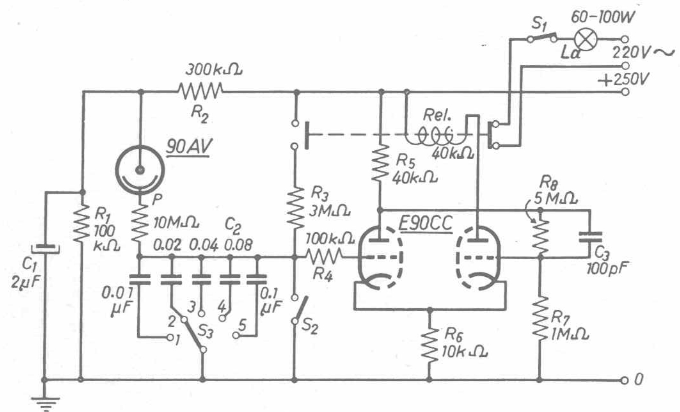

Fig. 1-1. Photoelectric exposure timer.

C_2 now starts to charge up positively (with respect to the earthed side) until finally the left-hand system of the double-triode conducts and the right-hand side cuts off. The relay is now de-energized and breaks the lamp circuit; at the same time another contact connects the grid of the left-hand system to the positive supply line via R_3, and the exposure is terminated. Opening S_1 and closing S_2 restores the circuit to its initial state.

For enlarging purposes, the value of C_2 can be altered to give different ranges, according to the distance from the light-source and the properties of the printing paper. With the component values indicated, and an illumination on the photocell of 60 lux, position 1 corresponds to an exposure time of 0.5 sec whilst in position 5 the time is ten times longer. The insulation resistance of the grid-to-cathode space of the E90CC is sufficiently high to allow exposure times of up to 100 sec for lower illumination levels.

Automatic Quantity Controller [40]

The photoelectric control device having the circuit shown in *Fig. 1-2* is capable of keeping the value of some physical quantity (e.g. pressure, temperature,

rotational speed, or the length of a workpiece, etc.) within two prescribed limits. The required value corresponds to a certain mean illumination of the photocell 90CG; the bridge circuit, of which the long-life pentode E80F forms a part, then delivers an output voltage of such a value that the left-hand thyratron PL2D21 is cut off and the right-hand thyratron is conducting. Potentiometer R_1 is for setting the nominal value, whilst R_2 and R_3 are for setting the upper and lower limits. As the illumination of the photocell is increased, the bridge output voltage goes more negative, so that when the upper limit is reached, both the thyratrons are cut off. Conversely, both the tubes conduct when the lower limit is reached. The relay contacts are so connected that when one of the limits is reached, the appropriate circuit is completed.
In order to prevent the apparatus reacting to momentary changes in the illumination, caused by short-term fluctuations in the nominal value of the controlled quantity, an *RC* element is included in the grid circuit of the E80F, and the time constant of this element is adjustable in five steps. In the sixth position, the *RC* circuit is switched off. With the values given, time constants of 0, 1.5, 3, 6, 12 and 24 sec are produced.

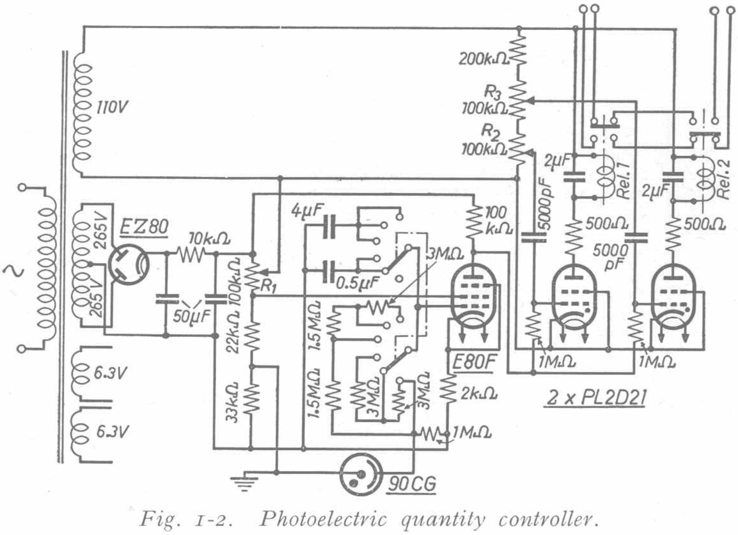

Fig. 1-2. Photoelectric quantity controller.

Control of Packing Machines

With packing machines it is frequently necessary to check for the presence of a printed stamp or of opening-tabs etc. For this purpose, use is made of a photoelectric scanning device, as shown in *Fig. 1-3*. A beam of light from the lamp *La* falls on the packing material and is reflected to the photocell *P*. The different-coloured opening-tabs, which are scanned at regular intervals, give rise to a momentary increase in the illumination of the photocell, causing negative-going voltage pulses to be passed via C_2 to the left-hand grid of the double triode T_1. If the tabs diminish the strength of the reflected beam instead of increasing it, then *P* and R_3 should be interchanged. The two systems of T_1

are connected in cascade so that negative voltage pulses, amplified by a factor of approximately 150, are produced at the anode of the right-hand system; these pulses are then fed via C_6 to the cathode of the left-hand system of T_2, which is connected as a diode, and the resultant direct current causes a voltage drop across R_1 and charges up C_7. The right-hand system of T_2 is also connected as a diode, the anode of which is given an adjustable negative bias by R_2. If the value of the voltage on C_7 exceeds the bias voltage, the right-hand system starts to conduct and cuts off the excess voltage. In this way, the pulses supplied from P, inasmuch as they only occur at regular intervals, give rise to a certain, definite voltage on C_7 whatever the actual amplitude of the pulses may be. This voltage of negative sign is present on the control grids of the two parallel-connected systems of the double-triode T_3, so that it prevents the relay *Rel* from operating. If, now, one pulse is omitted, owing to the absence of an opening-tab, C_7 discharges through R_1 until T_3 starts to conduct and an alarm is operated. Using the values of C_7 and R_1 given, operating times up to 1.5 sec can be chosen.

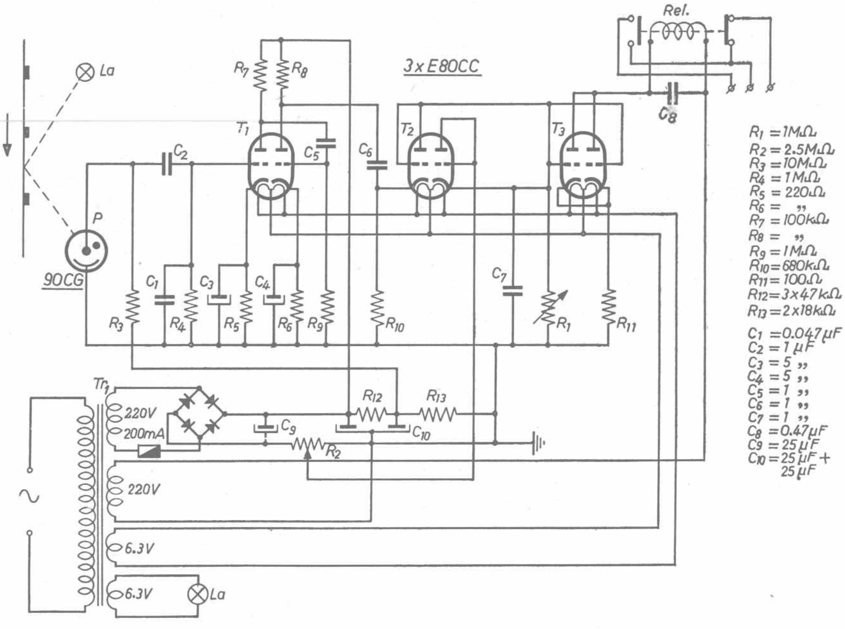

Fig. 1-3. Photoelectric scanning device.

When setting up the device for operation, the potentiometer R_2 is first so adjusted that all the pulses contribute an equal amount to the voltage on C_7. R_1 can now be adjusted for the pulse-frequency, i.e. for the working speed of the machine, so that during the intervals between the pulses the relay just does not operate.

For economic reasons, the apparatus has been fitted with only one type of tube (the E80CC). In certain circumstances, however, it may be advantageous to employ a thyratron in the output stage.

Photoelectrically Controlled Guillotine [41]

For cutting all kinds of material (e.g. paper, cloth, sheet-metal, etc.), a guillotine is employed, and this is normally automatic in operation, the cutting stroke being initiated, according to the length of material to be cut off, by regularly recurring marks or by some similar method. The circuit of *Fig. 1-4* can be used for this purpose: the guillotine is operated by means of an electromagnet, which has a coil, of impedance Z, connected across the output of a controlled three-phase rectifier. The thyratrons are controlled vertically; the control voltages, with 90° phase-displacement, are taken from three *RC* phase-shifting networks R_4C_4, R_5C_5, R_6C_6. In addition, there is a direct voltage

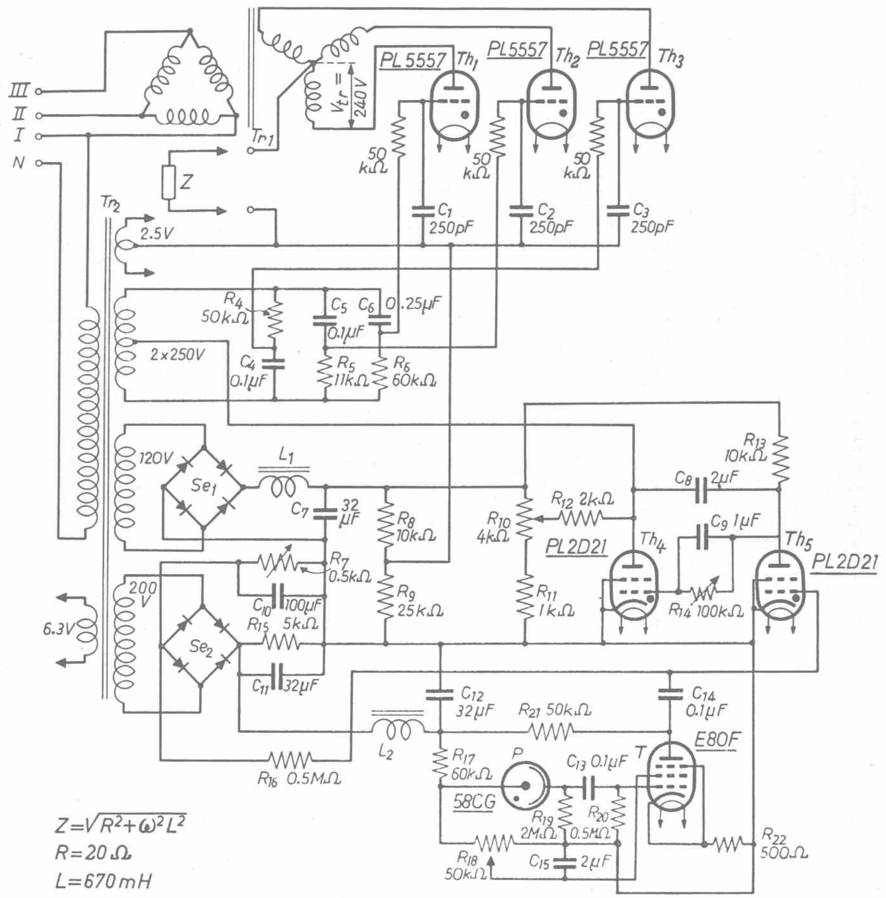

Fig. 1-4. Photoelectrically controlled guillotine.

component on the grids of the thyratrons, coming from a bridge circuit consisting of the resistors R_8, R_9, R_{10}, R_{11}, R_{12} and the small thyratron Th_4. Obviously, the tubes Th_1, Th_2, Th_3 are conducting when tube Th_4 is cut off. The firing angle and with it the current flowing through the coil of the guillotine can be adjusted as required by setting the potentiometer R_{10}. In the quiescent state, however, Th_4 is conducting since the grid of this tube is connected, via R_{14} and R_{13}, with the positive line of the power supply. The thyratron Th_5 on the other hand remains cut off since its grid gets a negative bias, the value of which can be set by means of R_7. Capacitors C_8 and C_9 have a charge of about 100 V, and if Th_5 is now struck by a pulse occurring on the grid, Th_4 will be extinguished because of the charge on C_8, and the guillotine will operate. Th_4 stays extinguished until C_9 has discharged, via R_{14}, to about 10 - 8 V, and with the component values indicated this comes about in approximately 0.25 sec. By decreasing the resistance of R_{14}, the time-interval can be shortened as required. Th_4 then strikes again and at the same time Th_5 cuts off owing to the fact that C_8 has meanwhile charged up again with reversed polarity; the initial state is thus restored.

The photocell P is illuminated by a beam of light reflected from the material which is being cut. When a mark appears, the illumination is temporarily reduced, and a negative pulse is thus passed to the control grid of the amplifying tube T. The positive pulse on the anode then strikes the thyratron Th_5 via C_{14}.

Counting Device for Mass Production Work [30]

It is sometimes necessary, in manufacturing processes, to count the number of operations occurring within a given interval of time, when the frequency of the operations may vary. This is the case, for instance, in measuring the output of semi-automatic machines such as a press, a punch, or a tablet-compressing machine, where it is necessary to check the uniformity of the products. The circuit of *Fig. 1-5* can be used with advantage in this connection. The operations to be counted are converted into electrical pulses by the photocell 58CV, and these pulses are then applied to the input of the 2-stage amplifier containing the pentodes E80F and E83F. At the output ot the amplifier a decade counter is connected, similar to that previously described [1]). The control grid of the E80F is connected to the anode circuit of the right-hand side of the double-triode E90CC, which is connected as a bistable multivibrator. If the right-hand system of the tube starts to conduct, the control grid of the E80F acquires such a high negative potential with respect to the cathode, that this tube cuts off and the pulses delivered by the photocell cannot reach the counter. The flip-flop stage is controlled by a second double-triode E90CC, which operates as a monostable relaxation oscillator. In the quiescent state the left-hand system of the tube passes current, whilst the right-hand is cut off. It switch S is momentarily closed, a negative pulse is produced on the control grid of the left-hand system, so that the tube switches over and a strong negative pulse is produced at the anode of the right-hand system. As a result of this, the flip-flop circuit now drops into the other operating state. The initial conditions are restored by means of switch S.

1) *R. Kretzmann:* INDUSTRIAL ELECTRONICS HANDBOOK, Philips Technical Library, Eindhoven, (Holland). II. 11.

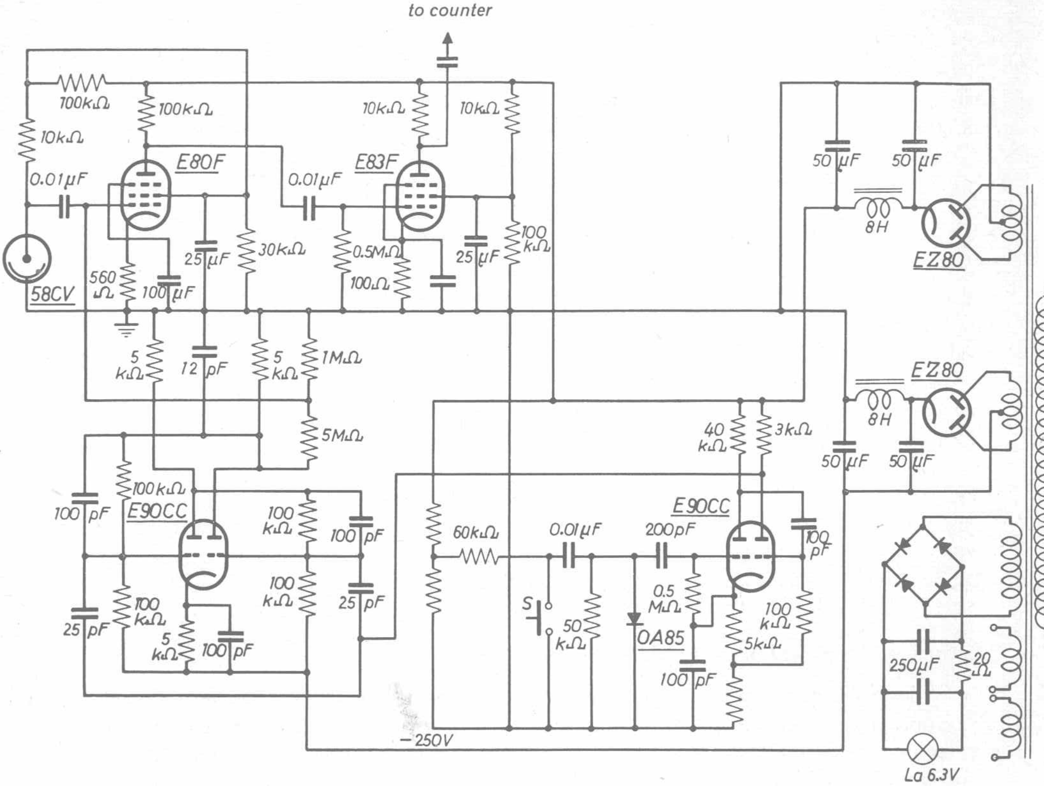

Fig. 1-5. Photoelectric counting device.

The lamp *La* illuminates the photocell and it is operated from a smoothed direct voltage in order to avoid interference pulses. The apparatus can also be used for determining very accurately the length of time intervals if, instead of the photocell, the output of a pulse generator of known frequency, say 10 kc/s, is connected to the control grid of the first amplifying tube. The counter then gives the time interval between two switching operations (switch *S*) in tenths of a millisecond.

Photoelectric Turbidity Indicator

The photoelectric turbidity indicator is a relay device with which small percentage reductions in light intensity can be detected and indicated when a certain limit is exceeded. Bridge-circuits incorporating two photocells are normally used for this purpose, the photocells being illuminated by two separate beams from a lamp. One beam passes through the measuring-space, whilst the other reaches the appropriate photocell directly. The bridge is balanced when there is no turbidity in the measuring-space. Such an equipment is, like all bridge-circuits, largely insensitive to fluctuations in the supply voltage, but it is rather expensive.

It was found possible to get the present apparatus to react steadily at the same value using only one photocell and one beam. This was done by stabilizing all the important voltages including that for the lamp. The relay then operated at a fluctuation of 5 % in the nominal illumination value. This is sufficient for most purposes.

The apparatus is particularly suitable for determining turbidity or colour changes in liquids, for smoke detection and other similar purposes. It finds application in all cases where the illumination of a photocell can be modified by changes in colour, transmission or reflection of a test specimen.

Fig. 1-6 gives the circuit of such a device for use as a smoke detector. It consists essentially of a photocell, a single-stage amplifier and a thyratron, which operates a relay. To achieve the necessary constancy, a high-vacuum cell (90CV) is employed, and for the same reason the amplifying tube selected is a pentode E80F, which has a very high grid insulation when underheated, thereby permitting the use of a grid leak resistor of 10 MΩ. This provides a satisfactorily high operating sensitivity. A power pack incorporating the EZ80 rectifier supplies the necessary direct voltages, and these are stabilized by two series-connected voltage stabilizers, type 85A2, so that a constant voltage of about 170 V is produced regardless of the mains fluctuations. The operating voltages for the photocell and the amplifying pentode are taken from a voltage divider, which is provided with a 5 kΩ potentiometer for controlling the cathode potential of the E80F and thereby the operating point of the tube. In this way the desired operating value of the thyratron circuit can be adjusted. The heater of the E80F is connected in parallel with the lamp. The heater voltages are stabilized by a series-connected current regulator tube 1913. The voltage of the heater winding is so chosen that the two heaters are operated at reduced voltages. This ensures long life and uniform light yield of the illuminating lamp and also takes advantage of the special electrometer properties of the E80F tubes.

The light-source is a 6.3 V/15 W filament lamp, the light from which passes

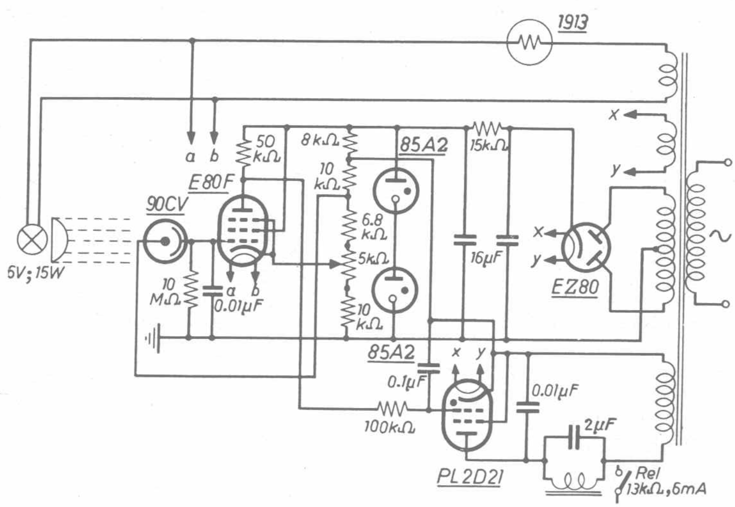

Fig. 1-6. Photoelectric turbidity indicator.

through a simple plano-convex lens of about 20 mm diameter and 40 to 50 mm focal length on to the cathode of the photocell. The almost parallel beam produced by the lens means that the length of the measuring-space between the light-source and the photocell can vary within wide limits.

The grid leak resistor of the E80F, which is also the external resistor of the photocell, has a value of 10 MΩ so that, even for small variations in the illumination, there is a big change in the grid voltage of the E80F.

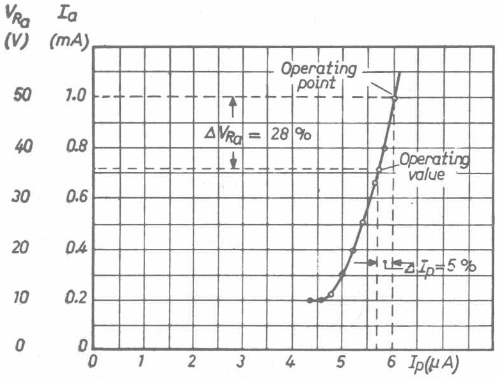

Fig. 1-7. Output voltage V_{Ra} as a function of the photocell current I_p.

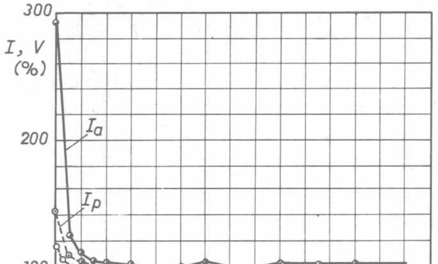

Fig. 1-8. The lamp voltage V_p, photocell current I_p and anode current I_a with respect to time.

The anode current of the E80F is adjusted to 1 mA by means of the 5 kΩ potentiometer when the illumination of the photocell is not dimmed. A voltage drop of 50 V is then developed across the anode resistor (50 kΩ), and the thyratron PL2D21 will be cut off by a negative grid voltage since the cathode has a constant positive potential. The negative bias at the grid of the PL2D21 is so chosen that the tube strikes for a change in grid voltage of approximately 14 V, which corresponds to a reduction in illumination of some 5 %. This provides a large measure of protection against smaller, arbitrary fluctuations. The sensitivity attainable with this apparatus can be seen from *Fig. 1-7*, which shows the relationship between the anode current or output voltage (d.c.) of the E80F and the photocell current I_p. When the light, and hence the photocell current, are reduced by about 5 %, the anode current changes by 28 %, and this gives a voltage sensitivity at the grid of the thyatron equal to 3 V per 1 % change in illumination.

Fig. 1-8 shows the operating values in relation to the starting time.

The diagram shows that the lamp and heater voltage V_p, the photocell current I_p and the anode current I_a of the E80F do not assume a reasonably constant value until after some 15 to 20 minutes; this is attributable to the behaviour of the iron-hydrogen resistor. At the end of the starting time the maximum fluctuations in I_a are about ± 3 %, which correspond to apparent changes in illumination of about ±0.6 %. If a 5 % change in illumination is required for operating the PL2D21 and the relay, there is an adequate margin of protection against spurious signals; this margin may be increased still further by means of the 5 kΩ potentiometer, but this means a loss of sensitivity.

The grid-to-cathode spaces of the E80F and the PL2D21 are bypassed by capacitors, in order to eliminate the effect of stray voltage pulses from any external source.

The electrical data are included in the diagram of *Fig. 1-6*. Particular attention should be paid to the screening and proper earthing of the photocell amplifier. The transformer specifications given below apply when using a high-resistance precision relay taking a small excitation power.

Mains transformer specifications

Primary winding:	220 V 0.5 A	Secondary winding *III*:	6.3 V 0.5 A
Secondary winding *I*:	2 × 230 V 15 mA	Secondary winding *IV*:	13 V 2.0 A
Secondary winding *II*:	220 V 20 mA		

Apparatus for Controlling Small Differences in Brightness or Colour Density [29, 31]

In printing, textile and chemical processes, slight differences in colour or brightness may pass unobserved through fatigue of the eyes. The equipment described below can be used for measuring and controlling such processes, and is independent of mains voltage fluctuations or differences in the intensity of the lighting. *Fig. 1-9* shows the circuit oı the apparatus. Two photocells are provided, one for the colour sample and one for the article to be tested (either 90AV or 90CV, according to the spectral range); the two surfaces to be compared are lighted from the same source (see *Fig. 1-10*).

The anodes of the photocells are supplied with a voltage of 85 V, which is stabilized by an 85A2. The grid leak resistors of two E80F amplifying pentodes serve as load resistors for the photocells; the cathodes of these pentodes can be balanced by a potentiometer of 5 kΩ. The screen grids are directly connected to the stabilized supply voltage of 85 V, and the anodes are each connected via

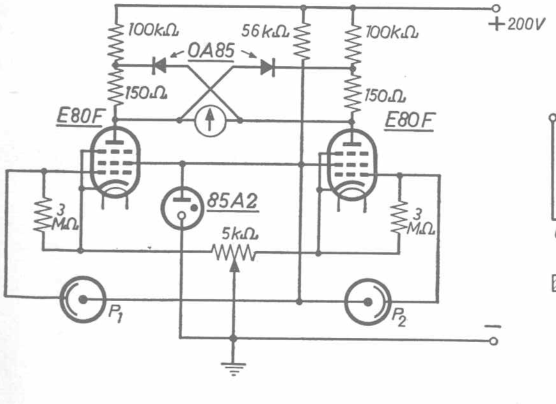

Fig. 1-9. Photoelectric device for control of brightness or colour density

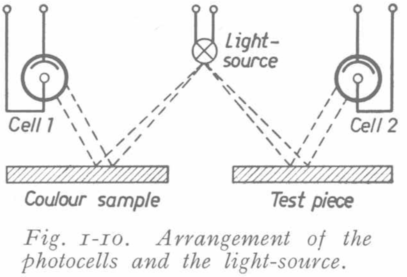

Fig. 1-10. Arrangement of the photocells and the light-source.

an anode resistor of 100 kΩ to a supply voltage of 200 V. A galvanometer having its zero in the centre of the scale and a range of —50-0-+50 μA is connected between the two anodes and is protected against overloading in both directions by biased OA 85 germanium diodes. The bias on these diodes is produced by resistors of 150 Ω connected in series with the anode resistors. A selenium rectifier with a smoothing circuit is used to deliver the 200 V supply voltage.
By means of the balancing potentiometer the working points of the two E80F tubes can be so adjusted that the galvanometer gives a zero reading when the test specimen and the colour sample are equivalent. Slight discrepancies between the cells and tubes can thus be compensated. Any difference in brightness or colour density is indicated by a deflection of the galvanometer pointer either to the left or the right. The stronger currents produced by very great differences can be taken up by the diodes as soon as their bias voltage is exceeded, and the galvanometer is thus protected.
Thanks to the bridge-circuit of the amplifier, mains voltage fluctuations up to ± 10 %, and fluctuations in the intensity of the light-source have practically no effect on the measurements. The scale of the instrument can be adapted for any particular requirements and, if necessary, it can be marked to indicate the permissible tolerance range.
To give a full-scale deflection of 50 μA a voltage change of 1.5 mV is required on the pentode grids. Using a grid resistor of 3 MΩ, this corresponds to a change in photocell current of 5×10^{-10} A, which means a change in illumination of about 2.5×10^{-5} lumens in the case of the 90CV photocell. An illumination change of 5×10^{-7} lumens is still easily readable.

Photoelectric Temperature Indicator [42]

The photoelectric temperature indicator described below can be used to great advantage in the heat treatment of large numbers of similar parts, thanks to its small, sharply defined optical field, its quick response and its high accuracy. When the desired temperature is reached, the indicator gives a signal or automatically switches off the heating, or causes the workpiece to be moved further on. The temperature indicator is not an apparatus for making absolute temperature measurements; it is a reliable device for accurately reproducing some predetermined heating level. In this respect it is superior to nearly all pyrometer type instruments, and offers great advantages in all hardening, forging and other heat-treatment processes.
In order to attain the desired high accuracy, the radiation, which is a function of temperature, is not directed straight at the measuring photocell, but is first modulated by means of a holed disc driven by a synchronous motor. The number of holes and the transmission ratio between the motor and the disc are so chosen, that a frequency of 281 c/s is produced. The resulting signal is passed to a selective AF amplifier, with which a far greater stability is possible than with the normal types of d.c. amplifiers, and which is free from hum interference by virtue of the frequency chosen. The amplifier, which operates a relay via a thyratron, can be adjusted within the working range of the device to make the relay operate at any desired temperature of the article under treatment. The circuit diagram of the apparatus is given in *Fig. 1-11.*

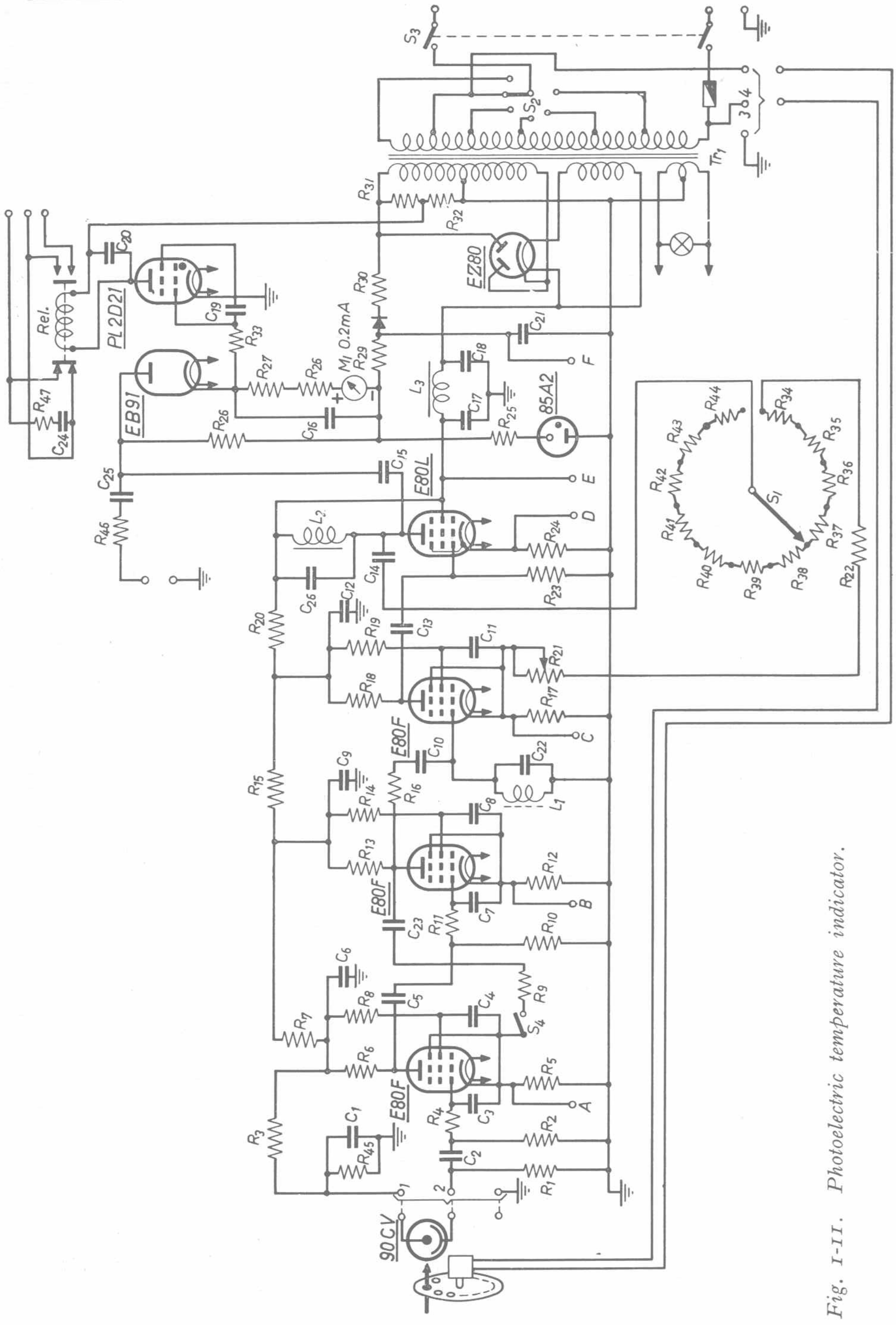

Fig. 1-11. *Photoelectric temperature indicator.*

Parts list for the circuit of Fig. 1-11.

R_1	10 MΩ	R_{20}	22 kΩ	C_1	0.1 μF	C_{20}	0.5 μF
R_2	5 MΩ	R_{21}	40 kΩ	C_2	0.01 μF	C_{21}	4 μF
R_3	1 MΩ	R_{22}	33 kΩ	C_3	470 pF	C_{22}	0.1 μF
R_4	100 kΩ	R_{23}	1 MΩ	C_4	0.1 μF	C_{23}	0.1 μF
R_5	2.2 kΩ	R_{24}	1000 Ω	C_5	0.05 μF	C_{24}	0.1 μF
R_6	220 kΩ	R_{25}	2.2 kΩ	C_6	4 μF	C_{25}	0.02 μF
R_7	47 kΩ	R_{26}	100 kΩ	C_7	470 pF	C_{26}	5000 pF
R_8	1 MΩ	R_{27}	100 kΩ	C_8	0.1 μF	L_1	Ferroxcube choke
R_9	470 kΩ	R_{28}	470 kΩ	C_9	4 μF		
R_{10}	1 MΩ	R_{29}	40 kΩ	C_{10}	0.05 μF	L_2	choke
R_{11}	100 kΩ	R_{30}	15 kΩ	C_{11}	0.1 μF	L_3	choke
R_{12}	2.2 kΩ	R_{31}	10 kΩ	C_{12}	4 μF	M_1	0.2 mA meter
R_{13}	100 kΩ	R_{32}	25 kΩ	C_{13}	0.05 μF		
R_{14}	1 MΩ	R_{33}	470 kΩ	C_{14}	0.1 μF	S_1	step switch
R_{15}	47 kΩ	R_{34}...R_{44}	33 kΩ	C_{15}	0.1 μF	S_2	mains adapter switch
R_{16}	47 kΩ	R_{45}	2 MΩ	C_{16}	0.1 μF		
R_{17}	2.2 kΩ	R_{46}	20 kΩ	C_{17}	6 μF	S_3	mains witch
R_{18}	220 kΩ	R_{47}	100 Ω	C_{18}	6 μF	S_4	single-pole switch
R_{19}	1 MΩ			C_{19}	220 pF		

The spot to be measured is focused on to the cathode of the photocell by a lens, which can be set so that its axis is lined up directly with the measuring point. The optical field is sharply defined, and this is a very desirable feature for the measurement of small articles or larger objects in which small sections are critical in respect of temperature.

The radiation from the test object, modulated by the holed disc, is converted by the photocell 90CV into an alternating voltage of 281 c/s, which reaches the grid of the first E80F via the capacitor C_2. All the amplifier controls are effected with the aid of adjustable negative-feedback circuits to prevent instability. The amplifier, which consists of three E80F pentodes and one E80L output pentode is split into two sections, each having its own adjustable negative feedback. In the first section, which consists of the first two E80F tubes, a fixed negative voltage-feedback is applied from the anode of the second tube to the cathode of the first and it can be switched on and off by switch S_4. There are thus two main sensitivity ranges, one incorporating negative feedback for the higher temperatures, and the other without for the lower temperatures. In the latter case, the stability of the amplifier is ensured by the negative current feedback across the two unbypassed cathode resistors R_5 and R_{12}. From the anode of the second E80F, the alternating voltage is passed via R_{16} and C_{10} to the grid of the third E80F, the grid circuit of which is tuned to 281 c/s by capacitor C_{22} and inductance L_1. The alternating voltage is then transferred via the *RC* coupling to the output tube E80L, the anode circuit of which is tuned to 281 c/s by means of L_2 and C_{26}.

The negative feedback in the second section, which comprises the third E80F and the E80L, also consists of fixed current feedback provided by the cathode resistors R_{17} and R_{24}, and a negative voltage feedback link from the anode of the E80L to the cathode of the third E80F. It is continuously adjustable with the aid of the step switch S_1 and the variable resistor R_{21}.

The alternating voltage delivered by the E80L is rectified by a diode EB91 and passed to the grid of the thyratron PL2D21 which is biased at a value of approximately —85 V by a metal rectifier. This grid bias is stabilized by an 85A2. The anode of the PL2D21 is fed via the relay *Rel* by an alternating voltage from Tr_1.

If the photocell receives no radiation, then no alternating voltage reaches the diode EB91, and the grid of the PL2D21 has the full negative bias of 85 V. The thyratron is cut off and the relay at rest. When the photocell is illuminated, a positive counter voltage is delivered; if this reaches approximately the absolute value of the negative bias, the thyratron strikes, the relay is energized and effects the desired switching operations.
The process can be followed on the instrument M_1 in the cathode circuit of the EB91. This meter is also used in setting the working point. In addition, there is an output for the connection of earphones, so that an acoustic check is also possible. The special measuring points A···F make it possible to carry out a rapid test on the amplifier without the housing being opened.

Automatic Tube Filling Machine [46]

Most automatic tube filling machines carry out the filling and sealing of the tubes entirely automatically. The following problem is encountered:
During filling, the tubes are held upside down at the screw caps in a special device; they are filled from the other end, which is then pressed over and sealed. Unless sufficient care is taken when setting the empty tubes on the machine they may be shaken out of place, so that they are sealed with the lettering in the wrong position. In this case the printing no longer appears on the flattened side of the tube, and this is obviously undesirable. The photocell device described below is of use in this connection. The tubes slowly rotate about their longitudinal axis while being filled, then a magnetic brake halts the rotation till the sealing operation has been completed. The current pulse for operating the magnetic brake is delivered by a photocell device at the moment when a mark on the wall of the tube alters the illumination of the cell. For this purpose the filament of a lamp is focused by a lens on to the edge of the tube, which bears a dark mark specially positioned with respect to the lettering. The spot of light produced on the tube is projected by another optical system on to the cathode of the photocell. This part of the equipment is enclosed in a special housing fitted to the machine and connected to the separate amplifier by means of a screened cable (see *Fig. 1-12*).
When the mark passes the spot of light on the edge of the tube, the light reflected to the photocell is weakenened, so that a negative pulse occurs on the control grid of the amplifying pentode E80F. C_2 forms with R_4, R_5 and C_3 a bandpass filter, which transmits the harmonics within its range but eliminates the basic frequency of rotation, which might be introduced by eccentricity of the tubes, and also the higher frequencies of any interference signal.
The negative pulse on the grid of the E80F gives rise to a positive pulse on its anode, and this is fed via C_5 and R_{13} to the grid of the thyratron PL2D21, which then strikes. The grid has a negative bias, which is applied by means of a germanium diode OA85. The value of the positive firing pulse can be adjusted by varying the gain of the E80F with different cathode resistors $R_6 \cdots R_{10}$.
Once the thyratron has struck, capacitor C_8 discharges via the magnetic brake *BM*, causing it to be momentarily energized. The rotation of the tube is now stopped, and the sealing operation is performed. A cam, fitted to the machine, then opens switch *K*, so that the thyratron cuts off and C_8 charges up once more via R_{15}, to the voltage supplied by the rectifier EZ80.