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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE MICROFLASH—A LIGHT SOURCE FOR ULTRA-HIGH-SPEED PHOTOGRAPHY

Also IN THIS ISSUE

● **THE PHOTOGRAPHY OF MOVING OBJECTS** by means of extremely short light flashes is rapidly becoming a familiar technique. Although associated in the popular mind mainly with the striking pictures of athletes, dancers, and others appearing in the press, this type of photography was first used for scientific and industrial purposes. A previous article* discussed the use of the General Radio Strobolux for single-flash photographs in industry. Like the available commercial equipment, however, the Strobolux is limited to those applications where a flash duration of 30 microseconds ($\frac{1}{30,000}$ second) will not blur the image.

There are many scientific and industrial problems where flashes of much shorter duration are required. An example occurring in the field of ballistics is the photography of projectiles in flight. A rifle bullet traveling at a speed of 2400 feet per second would travel nearly an inch in 30 microseconds. To record the bullet on photographic film without appreciable

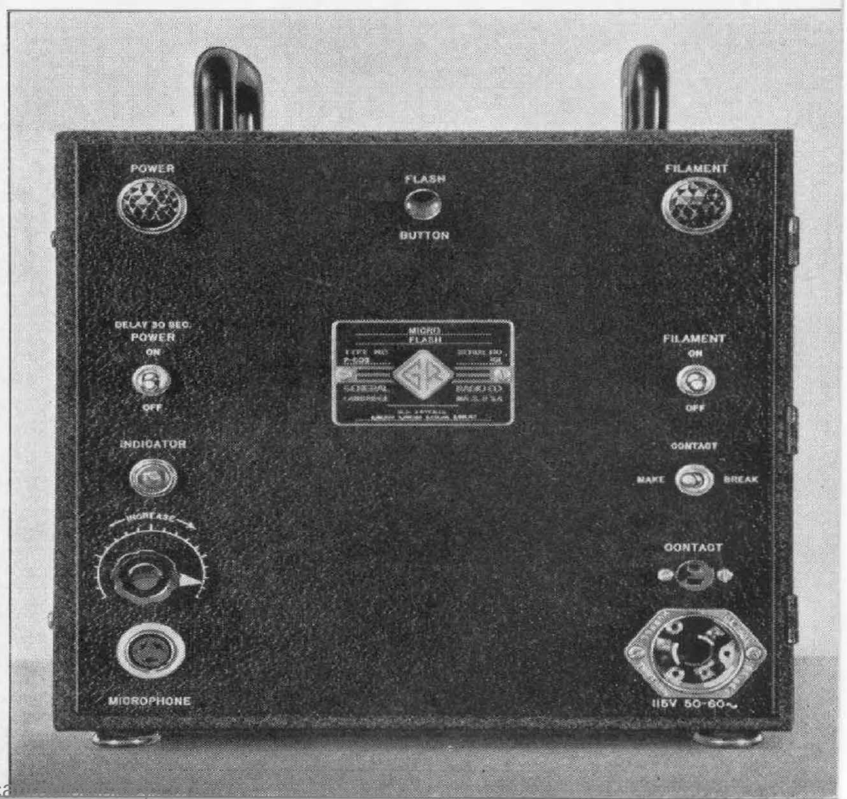

Figure 1. Panel view of the Microflash. The lamp is mounted in the rear of the case.

*J. M. Clayton, "Single-Flash Photography with the Strobotac and Strobolux," *Experimenter*, November, 1940.

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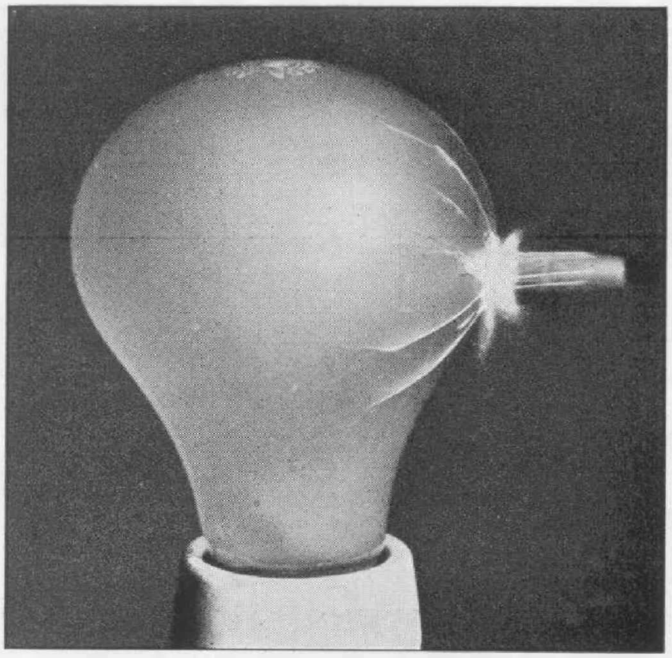

FIGURE 2. This photograph of a bullet entering an electric lamp bulb is an excellent example of the motion-arresting properties of the Microflash.

blur would require a flash duration no greater than about one microsecond.

To meet the specialized requirements of this and similar problems, the TYPE P-509 Microflash, shown in Figure 1, has been developed.† The functional diagram of Figure 4 shows the principle of operation. A high-voltage transformer and rectifier, operating from the a-c line, charge a condenser to a potential of about 7000 volts. Across the condenser is connected the flash lamp, filled with rare gases. When a pulse is impressed on the flashing electrode by the trigger circuit the gas in the lamp ionizes, producing a conducting path through which the condenser discharges. The discharge produces a brilliant flash of light lasting for about one microsecond.

The flashing circuit consists essentially of a gas-discharge tube working into an induction coil. A vacuum-tube amplifier is included to provide sufficient gain to permit operation from a conventional crystal microphone.

A microphone provides the most convenient method of triggering when the phenomenon to be photographed is accompanied by sound. For photographing a rifle bullet, for instance, the microphone is placed in such a position that

†Only a few of these instruments have been built, and they are not available for general sale.

FIGURE 3. A Microflash photograph of the explosion of a shotgun shell as it leaves the muzzle of the gun, which is out of the picture at the left. Note that the wads can be seen as well as the cluster of shot.

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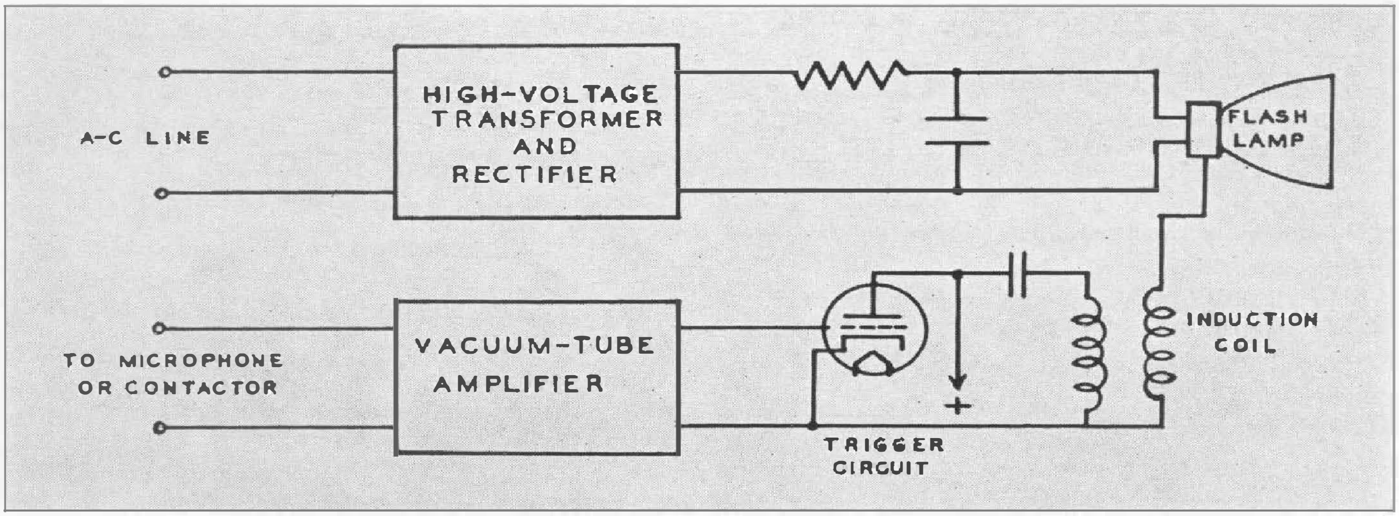

Figure 4. Schematic circuit diagram of the Microflash.

the sound of the report reaches the microphone at the same instant that the bullet passes the camera. Other methods of tripping the flash can, of course, be used, such as mechanical contactors and photo-electric cells. Conditions peculiar to each problem will usually determine the best method to use.

Figures 2 and 3 are actual photographs taken with the Microflash.

The Microflash is an example of the work being done by General Radio for National Defense. It will eventually lead to better stroboscopes for industry.

IMPEDANCE BRIDGES ASSEMBLED FROM LABORATORY PARTS

PART III — EXAMPLES OF MEASUREMENTS

● **THE DETERMINATION OF THE MAGNITUDES** of stray capacitance errors and the method of calculating the results of measurements with the series-resistance and Schering bridges may be made somewhat clearer through numerical examples.

Examples of actual measurements with both types of bridges are given below.

Series-Resistance Bridge

(a) Determination of C_{SG} and C_{PO} (see Figure 2, July *Experimenter*):

$$B = 10{,}000 \text{ ohms} \qquad C_N = 0.01\ \mu f$$
$$P = \text{Open-circuit} \qquad (1)$$
$$A = 13.6 \text{ ohms}$$

$$C_{PO} = \frac{13.6}{10{,}000}(0.01) \times 10^{-6} = 13.6\ \mu\mu f.$$

Reverse leads from transformer, at the bridge.

B, C_N, P, as above

$$A = 104.3 \text{ ohms} \qquad (2)$$
$$C_{SG} = \frac{104.3}{10{,}000}(0.01) \times 10^{-6} = 104.3\ \mu\mu f.$$

Change leads back to original connection, placing C_{SG} across C_N. In addition, 60 $\mu\mu f$ from the Type 602 is across C_N. The total value of the N arm capacitance is now 0.01016 μf (assuming the value of C_N to be exactly 0.01 μf).

(b) A measurement on a 500 $\mu\mu f$ air condenser with 10,000 ohms in series gave the following data:

$$B = 10{,}000 \text{ ohms} \qquad C_N = 0.01016\ \mu f$$
$$A = 510.1 \text{ ohms} \qquad R_N = 530 \text{ ohms}$$

$$C_P = \left(\frac{510.1}{10{,}000}\right)(0.01016) = 519\ \mu\mu f \quad (3)$$
$$C_X = 519 - 13.6 = 505\ \mu\mu f$$
$$D_P = (530)(0.01016)(6280) \times 10^{-6} = 3.38\%$$

For more accurate results a zero reading was made:

$B = 10{,}000$ ohms $\qquad A = 13.6$ ohms

$R_N = 747$ ohms $\qquad D_{PO} = (747)(6280)(0.0106) = 4.68\%$ (4)

$$D_X = \frac{(3.38)(519) - (4.68)(13.6)}{505} = \frac{1755 - 63}{505} = 3.33\%$$

The true values were known to be

$C_X = 503.7\ \mu\mu f \qquad D_X = 3.15\%$

Schering Circuit

(a) Determination of C_o

$A = B = 1000$ ohms

(approximately) 1000 $\mu\mu f$ in P arm (1)

$C_{N1} = 1092.3\ \mu\mu f$

$A = 10{,}000$ ohms $\qquad B = 1000$ ohms

$C_{N2} = 102.1\ \mu\mu f$ (2)

From Equation (1),

$$C_o = \frac{1092.3 - (10)(102.1)}{10 - 1} = 7.9\ \mu\mu f \quad (3)$$

(b) Determination of C_{SG}

$A = 100$ ohms $\qquad B = 1000$ ohms

P arm open

$C_N = 1004.1\ \mu\mu f$ (4)

From Equation (2),

$$C_{SG} = \tfrac{1}{10}(1004.1 + 7.9) = 101.2\ \mu\mu f \quad (5)$$

(c) Calibration of C_A

A calibration curve for capacitance increments of a TYPE 539-A Condenser is obtained by the substitution method described above.

(d) Measurement of dissipation factor of the zero capacitance in the P arm:

$A = 10{,}000$ ohms $\qquad B = 10{,}000$ ohms

P arm open, 539-A across A arm

$C_N = 93.6\ \mu\mu f$

$C_A = 498\ \mu\mu f$ (6)

$C_{SG} = 93.6 + 7.9 = 101.5\ \mu\mu f$

0.001 μf (TYPE 505-F) across P arm

$C_N = 1092.2\ \mu\mu f$

$C_A = 380\ \mu\mu f$ (7)

$C_{P2} = 1092.2 + 7.9 = 1099.9\ \mu\mu f$

$\Delta Q_A = \Delta C_A \cdot R_A \cdot \omega$

$= (500 - 380) \times 10^{-12} \times 10{,}000 \times 6280$ (8)

$= 0.00754$

From Equation (3),

$$D_{SG} = \frac{\Delta Q_A}{\frac{C_{SG}}{C_{P2}}} = \frac{.00754}{1 - \frac{101.5}{1099.9}} \quad (9)$$
$$= 0.0083 \quad = 0.83\%$$

(e) Establishing an initial dissipation factor balance:

$A = B = 1000$ ohms

1000 $\mu\mu f$ air condenser connected in P arm. The D of the P arm is then

$$D_P = \frac{D_{SG}C_{SG} + D_1C_1}{C_P} \quad (10)$$
$$= \frac{(0.83)(102.1) + (.004)(1000)}{1102.1} = 0.081\%$$

The condenser C_A is now set to a value corresponding to

$$\frac{D_P}{R_A\omega} = C_A = \frac{.00081}{1000 \times 6280} = (129)\ \mu\mu f$$

and balance established by means of a small air condenser across the B arm. The bridge is now ready for use.

As a check on over-all accuracy a measurement on a 0.001 μf mica condenser in series with 1000 ohms yielded the following data:

$A = B = 10{,}000$ ohms

$C_A = 102\ \mu\mu f$

$C_N = 1094.4\ \mu\mu f$

$C_X = (1094.4 + 7.9) - 101.2 = \mathit{1001.1}\ \mu\mu f$

$D_P = (10{,}000)(6280)(102) = 0.64\%$

$$D_X = \frac{(0.64)(1102.3) - (0.83)(101.2)}{1001.1} = \mathit{0.62\%}$$

These results compare very well with the (known) true values of 1002.3 and 0.65% for capacitance and dissipation factor, respectively.

As another example, the following data represent a measurement of a TYPE 505, 0.001 μf condenser, by a substitution method:

$C_A = 153\ \mu\mu f \qquad C_N = 1102.5\ \mu\mu f$

$C'_A = 102\ \mu\mu f \qquad C_N' = 104.2\ \mu\mu f$

$\Delta C_A = 51 \qquad \Delta C_N = 998.3\ \mu\mu f$

$$D_X = (1000)(6280)(51)(\times 10^{-12})\frac{1022.3}{998.3} = 0.035\%$$

$C_X = \Delta C_N = 998.3$

Accurate measurements on this condenser by our Standardizing Laboratory yielded:

$C = 998.6\ \mu\mu f \qquad D = 0.037\%$

— IVAN G. EASTON

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BRINGING THE CATALOG UP TO DATE

● **THERE HAVE BEEN A NUMBER OF ADDITIONS TO** and deletions from our line of instruments since the publication of Catalog K. In addition, several instruments have been temporarily discontinued in order that our facilities may be more efficiently used for the production of items needed for National Defense.

NEW INSTRUMENTS ADDED TO LINE

Type		*Described in EXPERIMENTER*
50	Variac	July 1939
318-C	Dial Plate	Dec. 1940
700-P1	Voltage Divider	Aug. 1939
701-A, -K	Dials	Aug. 1940
703-K, -L	Dials	Aug. 1940
717-K, -L	Dials	Aug. 1940
726-P1	Multiplier	May 1940
729-A	Megohmmeter (Battery Operated)	July 1940
740-BG	Capacitance Test Bridge	Feb. 1939
755-A	Variable Air Condenser	Aug. 1939†
757-A	U-H-F Oscillator	Aug. 1941
757-P1	A-C Power Supply	Aug. 1941
758-A	U-H-F Wavemeter	Aug. 1940
759-P35	Vibration Pickup	*
759-P36	Control Box	*
761-A	Vibration Meter	June 1941
769-A	Square-Wave Generator	Dec. 1939
774	Coaxial Terminals	April 1941
804-B	U-H-F Signal Generator	Feb. 1941
821-A	Twin-T Impedance-Measuring Circuit	Jan. 1941
25-A	Frequency Monitor (Consists of TYPE 475-C Frequency Monitor and TYPE 681-B Frequency Deviation Meter)	Jan. 1940†

*Descriptive folder available on request.
†Reprint available.

INSTRUMENTS REPLACED BY NEW MODELS

Type		*New Model*	*Described in EXPERIMENTER*
100-K	Variac	100-Q	July 1939
100-L	Variac	100-R	July 1939
475-B	Frequency Monitor	475-C	Jan. 1940
546-A	Microvolter	546-B	April 1941
561-C	Vacuum-Tube Bridge	561-D	
614-B	Selective Amplifier	614-C	
616-C	Heterodyne Frequency Meter	616-D	
675-M	Piezo-Electric Oscillator	675-N	

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Type			New Model	Described in EXPERIMENTER
681-A	Frequency-Deviation Meter	. . . .	681-B	Jan. 1940
695-B	Charging Equipment	. . . .	695-C	
696-B	Power Supply	. . . .	696-C	
716-A	Capacitance Bridge	. . . .	716-B	
759-A	Sound-Level Meter	. . . .	759-B	April 1940*
759-P1	Tripod and Cable	. . . .	759-P21	
834-A	Electronic Frequency Meter	. . . .	834-B	

*Descriptive folder available on request.

INSTRUMENTS DISCONTINUED

Type 70-A, -B Variac Transformers
Type 80-A, -B Variac Transformers
Type 90-B Variac
Type 138-A Binding Post
Type 138-D Switch Contact
Type 154-A, -B Voltage Dividers
Type 246-L, -M, -P Variable Air Condensers
Type 247-G, -F Variable Air Condensers
Type 274-K Binding Post Assembly
Type 274-L Binding Post Assembly
Type 293-A Universal Bridge
Type 293-P1 Bridge Transformer
Type 293-P2 Bridge Transformer
Type 293-P3 Slide Wire
Type 329-J Attenuation Box
Type 410-A Rheostat Potentiometer
Type 480-A, -B Relay Racks
*Type 516-C Radio-Frequency Bridge
Type 525-C, -D, -F, -H, -L Resistors
Type 544-P2 90-Volt Power Supply
Type 574 Wavemeter

*To be replaced by TYPE 916-A.

Type 578-AR, BR, CR, AT, BT, CT Transformers
Type 586-DM, -DR, -EN, -ER, -P5, -P6, -Q1 Power-Level Indicators
Type 613-B Beat-Frequency Oscillator
Type 625-A Bridge
Type 641-A, -B, -C, -D, -E, -F, -G, -H, -J, -K, -L Transformers
Type 664-A Thermocouple
Type 666-A Variable Transformer
Type 671-A Schering Bridge
Type 677-U, -Y Inductor Forms
Type 677-P1 Spacer
Type 678-P Plug Base
Type 678-J Jack Base
Type 682-B Frequency-Deviation Meter
Type 684-A Modulated Oscillator
Type 716-P2 Guard Circuit
Type 721-A Coil Comparator
Type 722-FU Precision Condenser (Unmounted)
Type 733-A Oscillator
Type 741-G, -J, -P Transformers

INSTRUMENTS TEMPORARILY DISCONTINUED

Type 202-A, -B Switches
Type 202-Y, -Z Knobs
Type 219-L, -N Decade Condensers
Type 334-F, -K, -R, -T, -Z Variable Air Condensers
Type 335-Z Variable Air Condenser
Type 505-R, -T, -U, -X Condensers
Type 526-A, -B, -C, -D Mounted Rheostat-Potentiometers
Type 539-X Variable Air Condenser
Type 611-C Syncro Clock
Type 642-D Volume Control
Type 646-A Logarithmic Resistor
Type 669-R Slide-Wire Resistor
Type 670-BW, -FW Compensated Decade Resistors
Type 739-A, -B Logarithmic Air Condensers

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NEW RESISTANCE VALUES FOR RHEOSTAT-POTENTIOMETERS

● **ALTHOUGH THERE ARE NO ACCEPTED STANDARDS** or preferred values for variable resistors, it is desirable, in order that a given resistance range be covered by as few models as possible, to standardize on a logarithmic distribution of resistance values. The values listed in our current Catalog K for General Radio rheostat-potentiometers are the outgrowth of customer demands, over a period of several years, for resistors to be used in particular applications. Most of the resistance values so determined no longer have any significance, as, for instance, the low-resistance models which originally met the NEMA standards for filament rheostats in vacuum-tube circuits.

In order to cover the available resistance range for a given type of unit more effectively, the resistance values have been revised to give an approximately logarithmic distribution for each model. A 1-2-5-10 system has been adopted for all models except TYPES 333 and 533, which already use a 1-3-10 system.

The new listings are as follows:

Type	*Maximum Resistance*	*Maximum Current*	*Code Word*	*Price*
301-A	5	0.9 a	PALSY	$1.00
301-A	10	0.65 a	REMIT	1.00
301-A	20	450 ma	RENEW	1.00
301-A	50	280 ma	RIFLE	1.00
301-A	100	200 ma	RIGID	1.00
301-A	200	140 ma	REBUS	1.00
301-A	500	90 ma	RIVAL	1.00
301-A	1000	65 ma	RAVEL	1.00
301-A	2000	45 ma	READY	1.00
301-A	5000	28 ma	ROMAN	1.00
*301-A	10,000	17 ma	CURRY	1.50
*301-A	20,000	12 ma	CRUMB	1.50
214-A	10	1.0 a	RURAL	2.00
214-A	20	0.7 a	RAZOR	2.00
214-A	50	450 ma	RAPID	2.00
214-A	100	320 ma	RIVET	2.00
214-A	200	220 ma	EMPTY	2.00
214-A	500	140 ma	ROSIN	2.00
214-A	1000	100 ma	ENACT	2.00
214-A	2000	70 ma	SYRUP	2.00
214-A	5000	45 ma	ROWEL	2.00
214-A	10,000	32 ma	RUMOR	2.00
371-A	1000	120 ma	REDAN	4.00
371-A	2000	90 ma	REFIT	4.00
371-A	5000	55 ma	ROTOR	4.00
371-A	10,000	38 ma	ROWDY	4.00
371-A	20,000	28 ma	RULER	4.00
*371-A	50,000	16 ma	SATYR	4.00
*371-A	100,000	11 ma	SEPOY	4.00
371-T	10,000	28 ma	SULLY	4.00
*314-A	1000	90 ma	DIVAN	4.00
*314-A	2000	65 ma	ENEMY	4.00
*314-A	5000	40 ma	ENJOY	4.00
*314-A	10,000	28 ma	DIVER	4.00
*314-A	20,000	20 ma	ENROL	4.00
*314-A	50,000	13 ma	DONAX	4.00
*314-A	100,000	9 ma	DONGA	4.00

(Continued on page 8)

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Type	Maximum Resistance	Maximum Current	Code Word	Price
*471-A	10,000	35 ma	ERECT	$6.00
*471-A	20,000	25 ma	HUMAN	6.00
*471-A	50,000	15 ma	ERODE	6.00
*471-A	100,000	10 ma	ERUPT	6.00
*471-A	200,000	8 ma	ESKER	6.00
333-A	1	8.5 a	VALOR	4.00
333-A	3	5.8 a	VAPID	4.00
333-A	10	2.5 a	VENUS	4.00
333-A	30	1.8 a	VIGIL	4.00
333-A	100	1.0 a	VIGOR	4.00
333-A	300	0.6 a	VILLA	4.00
333-A	1000	0.25 a	HUMOR	4.00
533-A	1	15.8 a	MOLAR	6.00
533-A	3	9.1 a	MONAD	6.00
533-A	10	5.0 a	MORAL	6.00
533-A	30	2.9 a	MOTTO	6.00
533-A	100	1.6 a	MUGGY	6.00
533-A	300	0.9 a	MUMMY	6.00
533-A	1000	0.5 a	HUSSY	6.00

*Supplied with linen-bakelite protecting strips.

Power ratings have been revised to give consistent values based on a temperature rise of approximately 50° to 60° C. above the ambient, except those for Type 333 and Type 533, which are based on a temperature rise of approximately 250° C.

Type	Power Rating	Type	Power Rating
301-A	4 watts	371-A with protecting strip	12 watts
301-A with protecting strip	3 watts	371-T	8 watts
214-A	10 watts	471-A	12 watts
314-A	8 watts	333-A	100 watts
371-A	15 watts	533-A	250 watts

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