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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

LIGHT METER FOR ELECTRONIC FLASH PHOTOGRAPHY

Also

IN THIS ISSUE

● **ALL PHOTOGRAPHIC** flash lamps, whether electronic or chemical, present a measurement problem that cannot be solved with the ordinary exposure meter, because of the transient nature of the light. What must be measured for flash photography is an integrated value of light vs. time, that is, exposure.

The Type 1501-A Light Meter has been designed to make this measurement, and it will be found particularly useful for color photography with electronic flash tubes (called speed lights or strobe lights), where accurate exposure determination is essential. This meter can be used to determine camera aperture with a given arrangement of

Figure 1. Panel view of the Light Meter, showing meter scale and controls.

lights or conversely to adjust lighting for correct exposure with a given aperture. With an auxiliary probe that attaches to the camera ground glass, it can measure the light actually reaching the film. Other important uses include the measurement of the light output of a flash tube, checking flash tubes periodically for deterioration, the measurement of reflector efficiency, and production testing by flash tube manufacturers.

Description

Functionally, the light meter consists of a light attenuator, a vacuum phototube, a capacitor, and a vacuum-tube voltmeter. Light reaching the phototube produces a current, which charges the capacitor. The capacitor voltage is indicated by the voltmeter.

A simplified circuit diagram is given in Figure 2.

The phototube is operated at a voltage high enough to insure that current is proportional to light. The integrating capacitor uses polystyrene dielectric to keep losses low so that no charge leaks off during the period required to take a reading.

The voltage across the capacitor is proportional to the integral of current (and, hence, of light) with time. The high input impedance of the vacuum-tube voltmeter permits the measurement of this voltage without drawing appreciable current, and it is this feature that makes the meter a practical device.

The switches shown in Figure 2 must be operated in the correct sequence to obtain proper performance. First the switch S_1 must be closed to remove any residual charge in the integrating capacitor. With the switch S_1 closed, the zero adjustment is set to bring the indicating meter to zero.

If continuous light falls on the phototube with S_2 closed, current will flow proportional to the light. When the integrating circuit is made active by opening S_1, the capacitor voltage will increase steadily and the meter will drift upscale. This is an undesirable condition when a flash is being measured.

The General Radio Light Meter has a combination push-button switch which serves the functions of S_1, S_3, and S_2 quickly and in proper sequence so that the integrated current due to continuous light will not seriously affect the meter reading. The sequence is as follows: Initially S_1 and S_3 are closed, and S_2 is open, with a spring to hold the switch in this position. A push results in, first, the opening of S_1 which activates the integrating part of the circuit, second, the closing of S_2 which flashes the flash tube and, third, the opening of S_3 which disconnects the phototube. As long as the switch is held in this final position, the meter will hold its reading. The meter returns to zero when the push button is released.

Other panel controls are provided for checking the condition of the batteries. The flash tripping circuit is connected to the meter by plugging into the panel jack.

Spectral Response

The spectral sensitivity of the light meter corresponds to the spectral sensitivity curve of the phototube, a 1P39-type, which peaks in the blue at 4100 angstroms and cuts off at 7000.

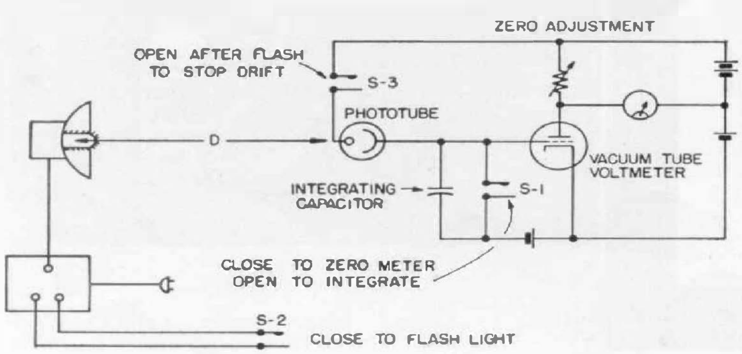


Figure 2. Elementary schematic of the electrical circuit.

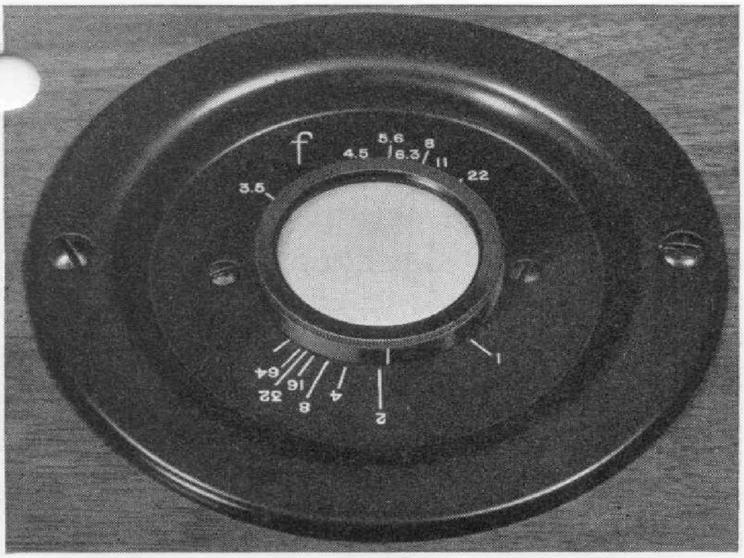


Figure 3. View of the light attenuator, showing f/scale and proportional scale.

Calibration

Light from a standard xenon-filled flash tube is used for calibration. The meter scale is calibrated directly in foot-candle-seconds (lumen-seconds per sq. ft.) of incident light from a xenon flash tube. Table I shows preliminary values of the required incident light at the subject in foot-candle-seconds for various photographic materials. Check measurements of these data are now being made by various manufacturers and users of sensitive photographic materials, and their recommendations will be published elsewhere when available. Until then, the preliminary data will serve as a rough guide for the initial use of the meter.

A Polaroid light attenuator is located on the front of the meter, over the phototube. This permits the range of the meter to be increased by factors of 2, 4, 8, 16, 32, and 64. Corresponding values of f/ numbers are also marked on the scale. A diffusion disk, mounted in front of the attenuator, adjusts the light transmission for correct calibration. This adjustment is made at the factory.

Exposure Determination—Incident Light

The light meter finds its greatest use in color photography in the professional studio, where it takes much of the guesswork out of exposure determination. The normal exposure for professional Kodachrome with average subjects is 100 lumen-seconds per square foot at f/3.5. This basic figure will, of course, be varied for different conditions and lighting arrangements as studio experience and practice indicates.

To measure exposure with a given lighting arrangement, the meter aperture is directed toward the key light, which is then flashed by pressing the CONTROL button and the meter indication noted. From the reading in lumen-seconds per square foot, the normal camera aperture can be determined from a table, or, alternatively, the light attenuator can be varied until the meter reads 100, and the corresponding aperture read from the f/scale of the attenuator.

Conversely, if a particular camera aperture is to be used, the attenuator can be set at that aperture and the key light moved in or out until the meter reads 100. For other types of film, the standard reading would be different, as indicated in Table I.

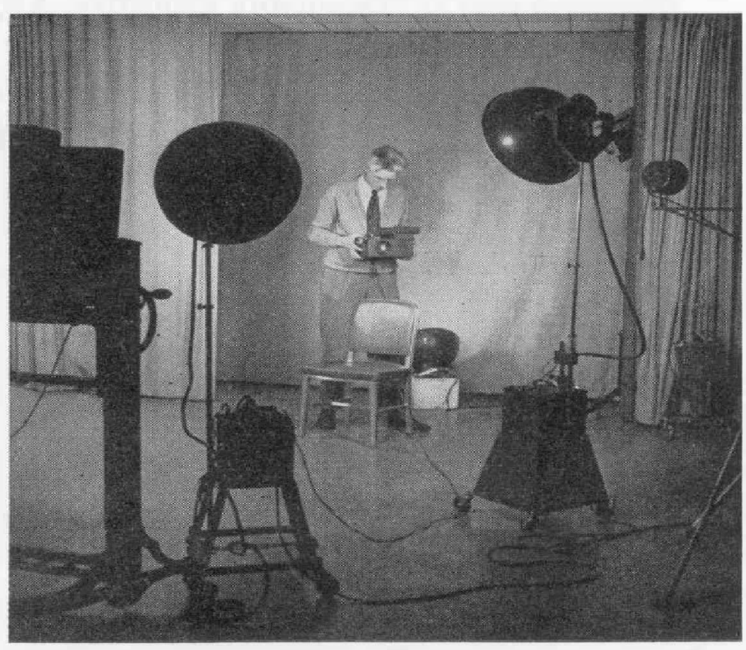


Figure 4. Light Meter in use in a photographic studio.

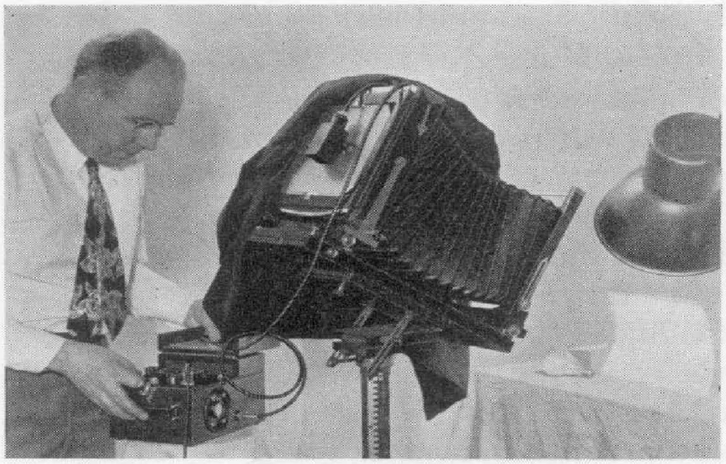


Figure 5. Illustrating use of Type 1501-P1 Probe to measure light reading film. Probe attaches to ground glass with two rubber suction cups.

Fill Lights

The contribution of each fill light is usually measured separately so that their values can be compared to the main key light. For flat lighting the fill may be half that of the key light, while contrast lighting may require one tenth. Experience is required in order for a photographer to get the result he desires. His experiments should be accompanied by light meter records so that he can use the light meter later to achieve the equivalent result.

Reflected Light at Ground Glass

The measurement of the light actually reaching the film is, of course, the most desirable way of measuring exposure. All factors influencing the exposure, such as aperture, lens absorption, and bellows extension, are then taken into account. For this measurement, an auxiliary probe is used. This probe attaches by rubber suction cups to the camera ground glass. The probe contains a photo tube and is connected to the meter through a cord-and-plug arrangement. Standard conditions are achieved by placing a white card at the subject. The image of the card is focused on the ground glass, and the probe is placed over this image. Thus only the light striking the film is measured.

Because of the difficulty of standardizing some of the factors influencing the reading, such as the absorption by the ground glass in different cameras, no calibration for the probe type of measurement is supplied. After a few test exposures with different aperture settings, the user can easily provide the desired calibration for his camera and meter. Since, for a given camera, film type, and meter, there can be but one correct reading, the lights and aperture are adjusted until this reading is obtained.

Other Uses

Two important uses of the light meter are the measurement of the output of flash tubes and of the performance of flash tubes in various reflectors. These are fully discussed in a recent article in the *P. S. A. Journal.*[1]

[1]Harold E. Edgerton, "Light Meter Uses with Electronic Flash," *P. S. A. Journal*, Part II, Photographic Science and Technique, January, 1950.

TABLE I*

Film	*Suggested Filter for Xenon Flash*	*Required Meter Reading (foot-candle-seconds) at f/3.5; Incident Exposure and Average Subject*
Kodachrome Prof. Film, Daylight Type	81-B	100
Ektachrome Prof. Film, Daylight Type	CCO5M	100
Kodachrome Daylight, 35 mm. and Bantam	81-B	80
Kodacolor (Roll only)	81-B	32
Ansco Tungsten# Color positive	Conv. 12	32
Ansco Daylight# Color Positive	CC44 + CC23	90

*Preliminary, subject to revision.
#Ansco recommends the Tungsten type for xenon flash. Processing influences effective speed.

SPECIFICATIONS

Light Range: A light range of 64:1 can be measured at mid-scale deflection, corresponding to 100 to 6400 lumen-seconds per square foot (foot-candle-seconds). The extreme readable range is about 50 to 12,800 lumen-seconds per square foot.

Attenuator Range: F/3.5 to f/22 corresponding to a range of 1 to 64 on the proportional scale.

Tubes: One RCA 929 and one RCA 124.

Batteries: One Burgess 2F, three Burgess XX30E.

Calibration: Meter is standardized in terms of a xenon flash tube operated from a known capacitor at a specified voltage. A diffusion disk is individually fitted to each meter to standardize the reading.

Special Characteristics: The phototube has maximum sensitivity in the blue portion on the visible spectrum.

Response Speed: For reliable results the flash should be 1/20,000 second (50 microseconds), or more, in duration.

Accessories Supplied: Tubes, batteries, diffusion disk, flash synchronizing leads.

Other Accessories Available: A probe for light measurements at the camera ground glass is available at extra cost. See price list below.

Dimensions: 7 x 6½ x 11 inches, overall.

Net Weight: 8⅛ pounds.

Type		*Code Word*	*Price*
1501-A	**Light Meter**	COCOA	**$190.00***
1501-P1	**Probe**	DANDY	**22.50***

*Including 25% Federal tax on photographic equipment.

A VARIAC* PHASE-SHIFT CIRCUIT

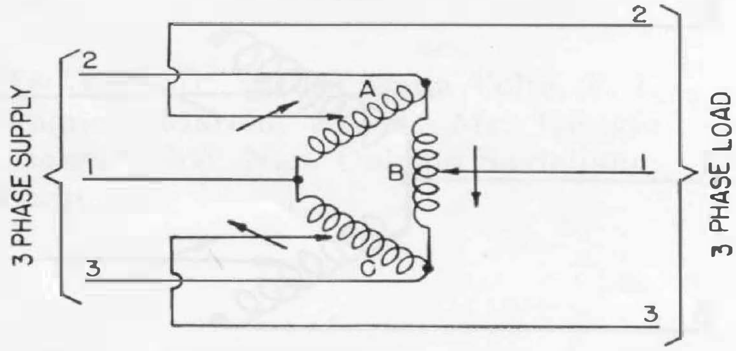
For years we have had to discourage our customers from attempting to operate Variacs in a closed-delta, three-phase circuit for voltage control. Figure 1 illustrates why this circuit cannot be used for conventional voltage control applications. As the brushes move in the direction of the arrows, brush *A* moves from phase wire 1 to phase wire 2; brush *B*, from phase wire 2 to phase wire 3; brush *C*, from phase wire 3 to phase wire 1. Figure 2 shows what occurs to the output during rotation. The voltage is reduced to 50% of its end value and then rises again, and the principal change is in the phase angle, which shifts 120° during rotation.

When, however, a convenient phase-shifter capable of operating smoothly and continuously over a 120° angle is required, this odd delta effect exactly fills the bill. For single-phase output, the closed delta is not needed, however, and an open delta assembly may be substituted as shown in Figure 3. Note that this differs from the conventional open delta three-phase control in that, as one brush moves from phase 1 to phase 2, the other brush moves from phase 3 to phase 1, this latter being opposite to the motion in the conventional open delta. The output, therefore, follows the curves of Figure 2. Obviously, some refinements of the circuit are possible, and the remainder of these remarks will be devoted to their development.

The first refinement concerns a means of correcting the voltage change accompanying the phase shift. Obviously, another Variac, as in Figure 4, will do this nicely. Note that the voltage correcting Variac in Figure 4 is shown *reversed*, in that the input is applied between brush and one end of the coil, from which

*Trademark Reg. U. S. Pat. Office. U. S. Patent No. 2,009,013.

Figure 1. Circuit for closed delta connection of Variacs.



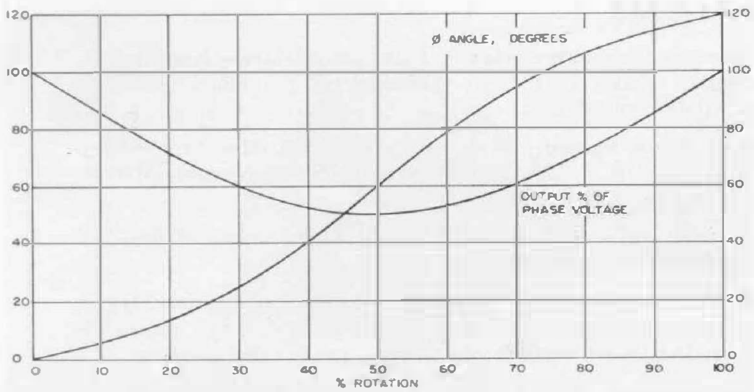


Figure 2. Variation of output voltage and phase angle in the closed delta as a function of dial rotation.

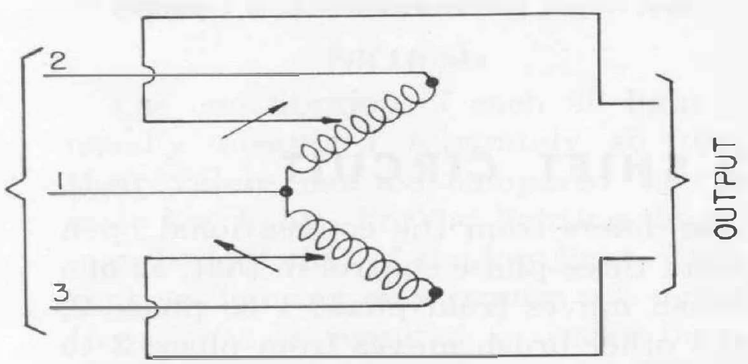


Figure 3. Connections for obtaining adjustable phase angle from open delta.

points output is normally derived. This connection calls for a reasonable amount of discretion in operation, since, *if the brush too closely approaches the low end of the winding, excessive and damaging currents will be drawn.* The use of, and observation of, a voltmeter during adjustment will guard against such difficulties.

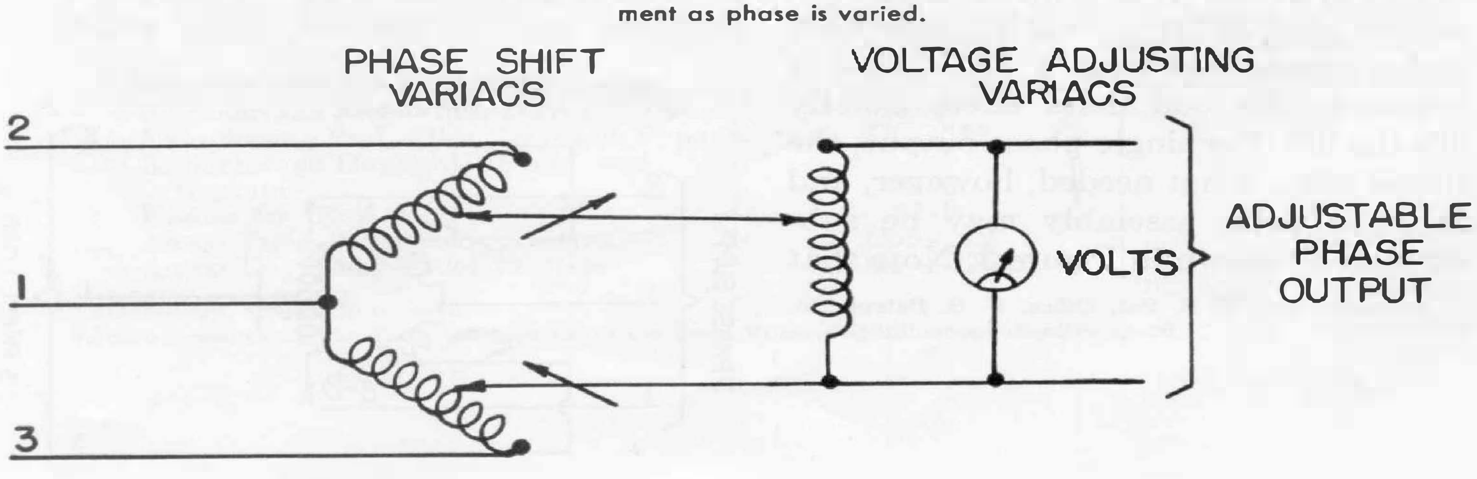
If, in Figure 4, phase 1–3 be considered the reference voltage, then, as the brushes move as indicated by the arrows, the phase angle will be changed smoothly to a maximum of 120° leading or lagging, depending on the phase sense of the supply. Since a phase shift of more than 90° is seldom required, Figure 5 illustrates an alternate circuit, in which the reference voltage is derived from one of the fixed taps on the Variac which are positioned at 14.8% and 42.5% of rotation. If "X" is chosen at 14.8% rotation, the adjustable phase output can be varied from 9° lead or lag to 111° lag or lead. If the tap at 42½% of rotation is used, the phase variation will be from 74½° lead or lag to 45½° lag or lead.

If a tap were made on the winding at 32.5% rotation, the range would be from 30° lead or lag to 90° lag or lead.

If a heavy load is to be drawn from the reference output, fixed autotransformers may be substituted for the Variac taps.

Still another possibility is shown in Figure 6 in which the overvoltage feature of the Variacs is used to secure a phase shift in excess of 120°. "Y" is 14.8% of the total winding (standard overvoltage tap). In this case the curves will vary somewhat from those given in Figure 2. The voltage will vary between 108.16% of line voltage to a low of 35.2% of line voltage, while the phase

Figure 4. Circuit showing the use of a third Variac for holding output voltage constant by manual adjustment as phase is varied.



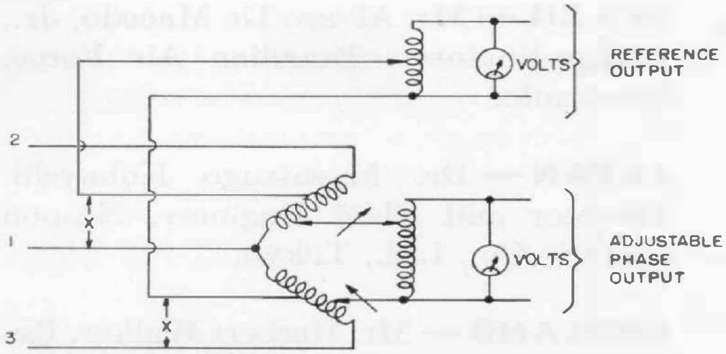


Figure 5. Circuit showing how reference voltage can be derived from fixed taps on Variac.

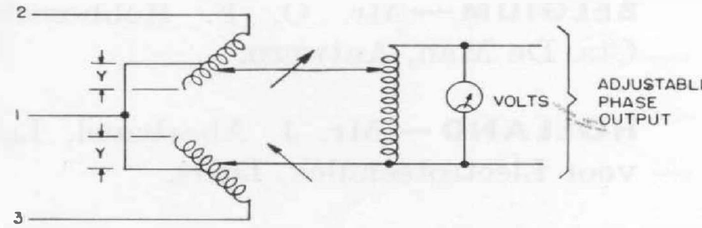


Figure 6. By connecting the input to taps, as shown, phase shifts of more than 120° can be obtained.

angle will vary from 6.89° lead or lag to 126.89° lag or lead. Note, however, that, if "Y" becomes as much as 50% of the total winding, the voltage will drop to *zero* at 50% rotation, though this connection yields a total phase shift of 180° (from 30° lead or lag to 150° lag or lead).

We hope that Variac users will find this discussion helpful in such applications as the testing of low power factor wattmeters, where a convenient phase-shift network is of material assistance.

— Gilbert Smiley

MISCELLANY

PAPERS PRESENTED—At the meeting of the Acoustical Society of America, Pennsylvania State College, June 22 and 23, 1950, "Calculation and Measurement of the Loudness of Sounds," by J. L. Marshall, L. L. Beranek, A. L. Cudworth, M. I. T., and A. P. G. Peterson, General Radio Company; "A Null-Balance Apparatus for Measuring Acoustic Impedance," by J. R. Cox, M. I. T., and W. M. Ihde and A. P. G. Peterson, General Radio Company. No copies of these papers are at present available for distribution, although both will be submitted for publication later.

At the Symposium on Improved Quality Electronic Components, Washington, D. C., May 9–11, 1950, under the sponsorship of AIEE, IRE, and RTMA, "The Need for Quality Performance in Laboratory Equipment," by P. K. McElroy, General Radio Company; "Reduction of Losses in Air-Cored Coils," by Robert F. Field, General Radio Company. These papers will be published in the *Proceedings* of the Symposium, obtainable from the Trilectro Co., 1 Thomas Circle, Washington 5, D. C., at $3.50, postpaid. Reprints of Mr. Field's paper are also available from the General Radio Company.

RECENT VISITORS from abroad to our plant and laboratories include:

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ITALY — Mr. Ettore Dalla Volta, F. I. Magneti Marelli, Milan; Mr. Giorgio Quazza*, Soc. Naz. Officine Savigliano, Turin.

BELGIUM—Mr. O. F. Robberecht, Cts. De Man, Antwerp.

HOLLAND—Mr. J. Abarbanel, Lab. voor Electrotechniek, Delft.

INDIA—Mr. K. Venkitaraman*, College of Engineering, Triuandrum.

IRAN—Mr. A. N. Nahavandi*, Tehran Faculty of Engineering, Tehran.

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BRAZIL—Mr. Alvaro De Macedo, Jr., Radio Engineer, Brazilian Air Force, Sao Paulo.

JAPAN—Dr. Masatsugo Kobayshi, Director and Chief Engineer, Nippon Electric Co., Ltd., Tokyo.

ENGLAND—Mr. Herbert Walker, Research Engineer, British Insulated Callender's Cables, Ltd., London.

*From the Foreign Student Summer Project, Massachusetts Institute of Technology.

THE TYPE 1501-A LIGHT METER described in this issue was developed by Dr. Harold E. Edgerton of the Massachusetts Institute of Technology, who also did the pioneer development work in speed-flash photography.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TRowbridge 6-4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WOrth 2-5837

LOS ANGELES 38, CALIFORNIA
1000 NORTH SEWARD STREET
TEL.—HOllywood 9-6201

CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WAbash 2-3820

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