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A SENSITIVE DIRECT CURRENT ELECTRICAL INTEGRATOR

The following article by Mr. R. W. Gilbert is reprinted from the May, 1947, issue of The Review of Scientific Instruments. *An addendum by Mr. Gilbert describes the Model 806 Light Integrating Relay and provides additional information on the electrical characteristics of the device.—The Editor.*

A permanent magnet-movable coil d.c. instrument mechanism is used as an oscillating relay for time integration of d.c. potential. It is operated in conjunction with an input-reversing relay and a vacuum-tube circuit to promote oscillation, the frequency of which is proportional to the input potential, and the number of oscillations is related to the potential-time integral.

In operation the accuracy of integration is within 1 per cent over an input-level ratio of over 100. And the energy demand from the source of input is comparable or less than that required to operate conventional d.c. indicating instruments.

THE INTEGRATION of electrical quantities against time is perhaps best typified by contemporary instruments such as the watt-hour meter and the ampere-hour meter. These provide a totalized running integral by indicating the totalized displacement of a motor whose velocity is proportional to the value being integrated. But the energy required for operation of the motor, which in turn must drive the totalizing counter, is demanded from the source, and sensitivity is thereby limited. Another distinct type of integrating instrument, the capacitor charge-discharge current integrator, is not so limited but requires voltage excursions that are prohibitive except for high voltage input devices such as phototubes.

The present device is not limited in either of these respects and is applicable to current or voltage magnitudes that are sufficient to operate conventional sensitive direct-indicating instruments. It is thus operable down to a few millivolts or microamperes, with input sources such as barrier-layer type photocells, thermocouples, thermal converters, Geiger counters, etc.

Method

The integrating mechanism proper is a permanent magnet-movable coil system similar to the structure used for d.c. indicating instruments. It, however, has no spring restoring force but is equipped with filaments to carry current to the movable coil with a minimum of mechanical torque. The coil is a so-called "frameless" type having no metal frame as generally included for damping in indicating instruments. The movement is arranged as a relay to engage contacts at the extreme ends of coil motion, as shown in Figure 1.

When a potential is applied to the movable coil, the resulting current will cause the coil to move at a velocity where the e.m.f. generated by its motion will balance the applied voltage, less a small amount required to support frictional losses. The coil velocity will therefore be

In This Issue

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proportional to the applied voltage, and so the total angle traversed by the coil will be proportional to the voltage-time integral, as

$$\int edt = NBA\theta, \quad (1)$$

wherein all factors are in fundamental units, as follows: N—number of turns on the movable coil, B—air-gap magnetic flux density, in gauss, A—effective area of movable coil, in sq. cm., θ—angle traversed by movable coil, in radians, $\int edt$—input potential-time integral, for angle θ, in abvolt-seconds.

The contacts are connected to an appropriate circuit which includes a reversing relay whereby the input voltage applied to the movable coil is reversed in polarity at each end of the coil travel. It will thus oscillate in response to the applied potential at a frequency proportional to the applied voltage. The number of cycles of oscillation may then be counted to obtain a running time integral of the input voltage.

The basic circuit arrangement is shown in the block diagram of Figure 2. The block component indicated as a trigger circuit is designed to trip in response to a momentary contact of the integrating relay, to reverse the reversing relay until the opposite contact is engaged, again tripping to again reverse the input. The over-all circuit operates essentially as a d.c. motor with an external commutation device. But the integrating relay mechanism has an efficiency at low levels far greater than devices normally classed as motors, and the energy demand is extremely small in comparison.

Practical Operating Circuit

When the integrating relay is moving at a low velocity in response to a low level of input voltage, the pressure available for operation of the relay contact is negligible, and reliability of contacting is a problem. But by operating the contacts in a high-voltage low-current circuit, for example at 100 volts through 1 megohm, contact operation is reliable regardless of the velocity with which the contact is approached. Also, an occasional tendency for mechanical adherence after contacting must be recog-

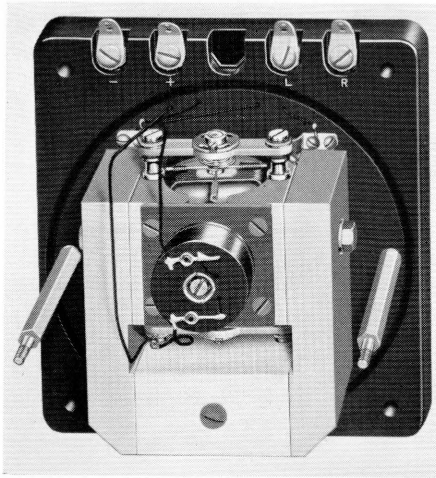

Figure 1—Permanent Magnet—Movable Coil Integrating Relay Assembly.

nized if operation at low input levels is expected.

As a solution to these problems, the circuit of Figure 3 has been used with complete success. It can be recognized as a cross-connected amplifier or conductively coupled multi-vibrator known generally as a "trigger" or "flip-flop" circuit. In the steady state one tube only can be conducting at a time, and if the non-conducting tube is momentarily forced to conduct, the circuit will reverse to a new steady state condition wherein the previously blocked tube is conducting and the previously conducting tube is blocked, and *vice versa* when the cycle is continued. The integrating relay contacts are connected to the coupling network which can supply the desirable high-contact voltage and contain the necessary high resistance to limit the contact current. The circuit will reverse within a time interval that is small relative to the time of any mechanical motions such as bouncing of the integrating relay contacts, and the nature of the contact will not delay reversal.

A resistance-capacitance circuit is included, as shown, to free the contacts should they adhere mechanically. This injects a momentary surge current into the movable coil in response to the transitional plate voltage change when the circuit reverses.

As a matter of convenience and symmetry, the input-reversing relay is operated from the plate circuit of one tube, and a relay for operating the counting device is operated from the plate circuit of the other tube. The counter can be any electro-mechanical counter suited to the specific application, and may include a control circuit designed to operate at a predetermined count.

Design Considerations

The operating circuit, as distinguished from the integrating relay proper, is purely functional and has no direct bearing on performance if it simply functions properly. For example, tube coefficient changes within design limits will have no effect upon operating accuracy.

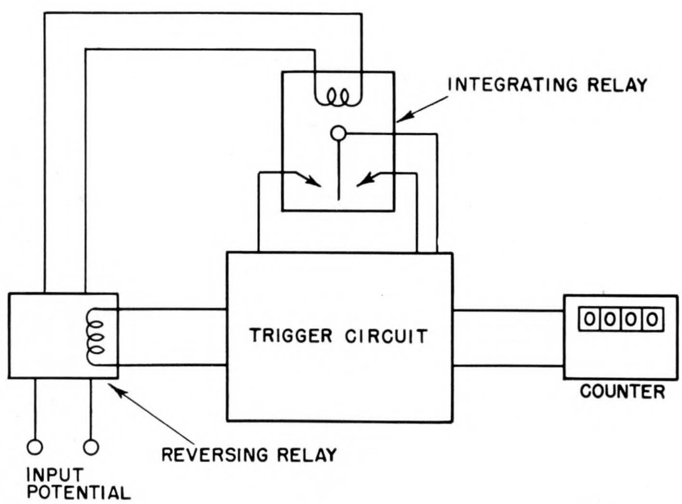

Figure 2—Block Diagram of Operating Arrangement.

The one possible exception is the reversing relay, which should operate within a small time interval relative to the time required for a cycle of integrating relay operation; otherwise, reversal of the input to the movable coil will be delayed and a low reading error will result. So the integrating relay is the primary determinant of performance, and its design precautions are of direct interest.

In operation it will be noted that at very low and very high input values, corresponding to low and high operating frequencies, an increasing error will develop in the low direction. At low operating levels this error is the result of pivot friction and unavoidable residual spring torque in the integrating relay movement. At high levels error is caused primarily by reversing relay delay and by air-resistance drag on the movement. An additional source of appreciable error could be mechanical energy loss in the contacts, but by using a resilient contact structure having a low-loss factor this source is negligible relative to relay delay and air resistance. The contacts used in practice assure that the mechanism will rebound with little loss of velocity.

The error developed against operating frequency will therefore appear as shown in Figure 4, which was determined for a typical relay used with the circuit of Figure 3. The error is expressed as a ratio of the ideal operating frequency against the actual developed frequency; the ideal being the frequency at which the reaction potential developed by the moving coil would equal the applied potential. The characteristic is identical to the "slip" ratio exhibited by a d.c. motor.

The error-frequency relationship is necessary for a practical determination of the optimum operating frequency, which would be the design center of the range of input level, and for the range of input level that can be accommodated for the accuracy required. From this relationship the integrating relay can be adjusted high by an appropriate amount to provide the best over-all accuracy over the required range of input level accommodation; a small high error will then persist at median levels and a small low error at each extreme.

Note that the optimum fre-

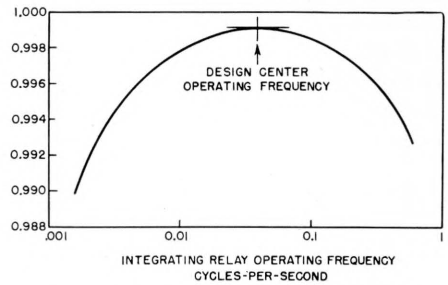

Figure 4—Typical Error Characteristics.

quency represents a periodicity of about 20 seconds for this typical case, largely caused by a high flux density and proper pivot, jewel, and spring designs. At shorter periods, reversing relay cross-over time becomes apparent, and, at still shorter periods, square-law air resistance becomes dominant.

In practice it is generally necessary to design the integrating relay so that a cycle of operation represents some specific even multiple of potential-time integral. This is best done by first determining the maximum available stabilized magnetic flux density, calculating the appropriate number of movable coil turns, and performing the final adjustment by means of screw adjustment of the contact spacing angle.

Performance

The typical Weston Model 806 Integrating Relay, illustrated in Figure 1, develops a stabilized flux density of about 4,700 gauss, has an effective moving coil area of about 9 square centimeters, and a nominal contact angle of 90 degrees. Using the relationship (1) and reducing to practical units, this calculates to a potential-time input integral of 1.33 millivolt-seconds per movable coil turn per cycle (2×90 or 180 degrees). Thus if equipped with a 100-turn movable coil it would oscillate one cycle for each 133 millivolt-seconds, or would oscillate at a frequency of 1 c.p.s. if a potential of

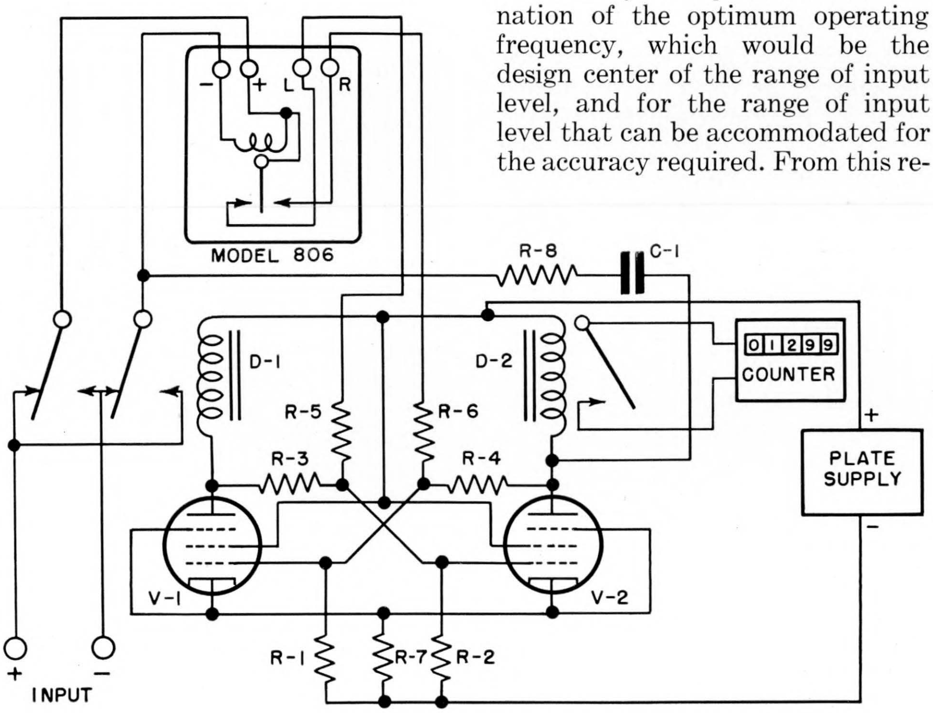

Figure 3—Operating Circuit.

Suggested Circuit Constants

R-1 to R-6 . . . . . *Two megohms, ¼ watt, 20%.*
R-7 . . . . *5,000 ohms, 5 watt, 10%.*
R-8, C-1 . . . . . . *Values vary with range of Model 806. Time constant (RC) of about 1 millisecond, with sufficiently high resistance and low capacitance to have no influence upon calibration. (R-8—10,000 to 500,000 ohms, C-1—.1 to .002 mfd.)*
V-1, V-2 . . . . . . *Type 6V6 pentode, or similar pentode or beam tube.*
D-1, D-2 . . . . . *Telephone Type Relays, with approximately 5,000 ohm coil.*
Plate Supply . . . *250 volts, d-c, 20 ma demand, 5% ripple maximum, regulation not important.*
NOTE—The power line must be isolated from the circuit by a transformer if the input circuit is grounded.

133 millivolts were applied, etc. As coils can be wound within practical limits from about 25 turns to 1,500 or more turns, choice from about 35 to 2,000 millivolt-seconds/cycle is available.

In operation the frictional losses require a driving torque, which in turn is derived from the current demanded from the input source. This operating loss current then develops a potential drop through the circuit resistance, which is essentially the resistance of the movable coil plus the resistance of the input source. To complete the circle, this potential drop is the difference between the applied voltage and the reaction e.m.f. developed by motion of the movable coil, and its magnitude in relation to the applied voltage is expressive of the operating error. It thus is necessary to have a movable coil of minimum resistance, which is a function of internal design, and to apply the instrument only to sources having a resistance not large with respect to the movable coil resistance, which is a function of the application. Where appreciable resistance in the source is unavoidable, the optimum is a movable coil having a resistance that matches the source, provided the resultant calibration adjustment is permissible. In any event, the instrument as a class is limited to input potential sources having a resistance not very much larger than practical movable coils can be wound, which is about 2,000 ohms.

Fortunately, the potential balance condition established by the reaction potential of the movable coil causes the current demand from the source to be much less than would be determined by the resistance of the movable coil only. In effect, potentiometric balance is established. Thus the temperature coefficient of resistance of the moving coil is ineffective and no temperature compensation is required. Also, lead resistance between the input source and the instrument will have a relatively negligible effect, and calibrated leads such as used with indicating millivoltmeters are not required.

Current Integration

The integrating of current rather than potential requires addition simply of a shunt to derive a proportionate potential, which is integrated as described. In this case the lower limit of current is determined by the maximum shunt resistance that can be tolerated in the circuit, which in turn is determined by the maximum resistance movable coil it is feasible to wind.

If the foregoing typical integrating relay constants are assumed, and the relay is equipped with a 1,500-turn coil having a resistance of 2,000 ohms, the design center operating frequency of 0.05 c.p.s. calculates to an applied potential of about 100 millivolts. If a shunt that matches the coil in resistance is used, which is optimum, the design center of input current would be 50 microamperes.

Addendum:

The Weston Model 806 Integrating Relay

The Model 806 Relay is designed as a component of the Model 807 Light Integrator. However, it is available separately, and is fully cased for inclusion in special integrating devices without special cover protection. It is equipped normally with four terminals, two for the movable coil (− and +) and two for the stationary contacts (*L* and *R*), with the (+) terminal common to the coil and the movable contact. Potential applied in the polarity indicated will cause the (*R*) contact to engage, and *vice versa*.

The case is designed for vertical mounting with the terminals at the top; other positions will develop additional pivot friction and are not recommended where good accuracy or low operating levels are required. Also, as in the case of all d.c. instrument mechanisms, mounting on a steel panel will cause magnetic shunting and a special adjustment is required.

The contacts are faced with tungsten for wear and arc resistance, and have a life expectancy exceeding five million operations without cleaning or dressing.

Two basic types are available for integration of current or voltage. The current type is similar to the voltage type but includes an internal shunt resistor to develop the potential for operation of the coil. The nameplate is marked with the adjustment in terms of one full cycle of coil swing, usually millivolt-seconds or milliampere-seconds, the shunt resistance in the case of the current type, and the recommended maximum and minimum operating levels.

By choice of movable coils, the Model 806 can be adjusted to values between about 35 and 2,000 millivolt-seconds/cycle, assuming the use of maximum available magnetic flux density and contact angle. The coil resistance will be approximately equal to the adjustment in volt-seconds squared, times 1,000, a corresponding resistance range of about 2 to 4,000 ohms. When equipped with a matching shunt, the corresponding highest current integral sensitivity is about 0.5 milliampere-seconds (0.0005 coulomb).

In selecting a proper adjustment, the usual determinant is the average input level as estimated. This, as a design center level, can be divided by the design center operating frequency to obtain the corresponding adjustment, which can be weighted to the nearest round figure.

The curve of Figure 4 was determined by actual test run on a new instrument, and indicates a design center operating frequency of about 0.05 second. But in practice it is advisable to allow for some eventual increase in friction which will shift the optimum frequency upward. A design center from 0.1 to 0.5 second is therefore recommended, with the higher frequency favored where accuracy will permit.

E. N.—No. 43 —*R. W. Gilbert*

NOTICE

The second article on Thermal Problems Relating to Measuring and Control Devices by Mr. W. N. Goodwin, Jr., will appear in the April issue of Weston Engineering Notes.

The first article on Thermal Problems published in the December issue discussed the fundamental laws of heating and cooling of simple bodies. Part Two will continue this subject by considering the lag in temperature and intermittent heating and cooling of simple bodies.

WESTON MODEL 807 LIGHT INTEGRATOR FOR THE PHOTO-MECHANICAL INDUSTRIES

THE Model 807 Light Integrator has been especially designed to meet the requirements of the photographer engaged in photo-engraving, lithography or gravure work. It employs a sensitive direct current electrical integrator of the type described in the preceding article by Mr. R. W. Gilbert. By means of a photoelectric cell mounted on the copyboard, printing frame or other desired location, and connected to the Light Integrator, correct photographic exposures are possible regardless of lamp fluctuations or even temporary power failures. As the name implies, the instrument measures the sum total light quantity irrespective of the time necessary to deliver the correct quantity. Thus, if the light intensity drops 10 or 20 per cent, the time will automatically be increased, hence for a given dial setting the photographic exposure will always be the same. The system of using Timers merely considers the exposure time, and this can only be correct if the light remains constant. Arc lights flicker continually and occasionally fail for short periods of time, low voltage results in low light intensity, high voltage in high light intensity, glasses and diffusing screens get dirty and transmit less light, etc. It is obvious that the measurement of time only is not a good criterion of exposure. Because the integrator considers both functions of exposure, *Light* and *Time*, it is a true exposure meter and its use will result in much more uniform photographic results than has heretofore been possible. Experimental models of the integrator, which have been in use in several photo-engraving and gravure shops for some time, have proved the necessity of controlled exposure.

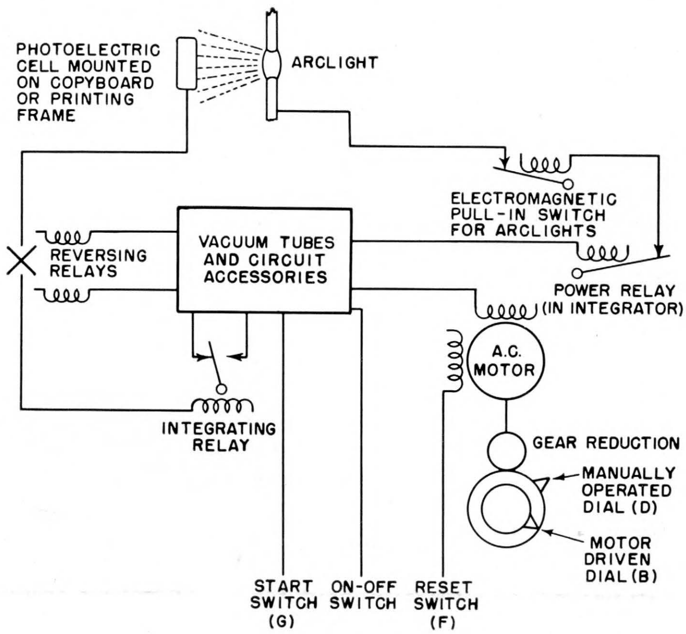

Figure 2 — Schematic Diagram Showing Principle of Operation of the Weston Light Integrator.

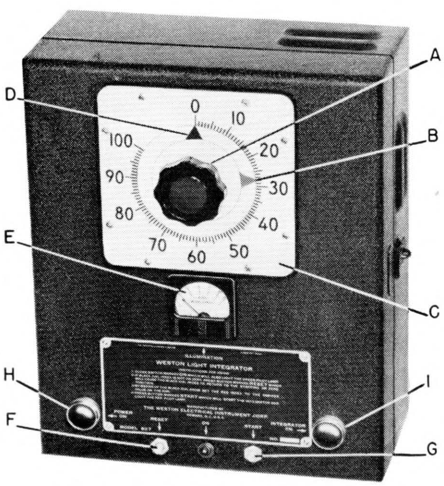

Figure 1—The Weston Model 807 Light Integrator.

The Integrator

Figure 1 shows the integrator case and external parts. By means of the knob (A), the red index (B) can be set to any desired exposure setting on the dial (C). The dial (C) is always furnished with a 0 to 100 scale, but by means of a factor these dial values can be easily converted to meter-candle-seconds. Thus, if an integrator has a range of three million meter-candle-seconds, and the dial is set at 40, the exposure will be 40 per cent of 3,000,000, or 1,200,000. In most cases the actual value will only be of use to the technician, as the operators merely use the dial settings and are not concerned with the exact exposure equivalents. As the integrator responds to the light on the photo-cell (Figure 2), the black index (D) advances toward the red index (B) and when the two indices are coincident, an electrical contact is broken and the arc lights are extinguished. If exact duplicate exposures are desired, the red index (B) can be left in its original position and by depressing the "Reset" button (F) the black index (D) will be motor driven back to the zero position. Then by depressing the button (G) marked "Start" the arc lights will be automatically lighted and the integrator will function over again.

The pilot lights (H) and (I) are red and green, respectively. The red light (H) indicates when the power is on the integrator. The green light (I) indicates that the integrator is functioning. The indicating instrument (E) is calibrated to read the illumination on the photoelectric cell and by means of this the copyboard or printing frame can be checked for light uniformity by merely placing the photoelectric cell in various positions on the board.

The integrator is designed for use on 120 volt-60 cycle circuits and is not available for direct use on any other circuit. For some installations, certain accessories will be required and these are described later.

The general design is such that the integrator is accurate and reliable and at the same time rugged enough to meet commercial requirements. The dial is large enough to be readily seen even in the low illumination levels of the photoengraving and gravure darkrooms.

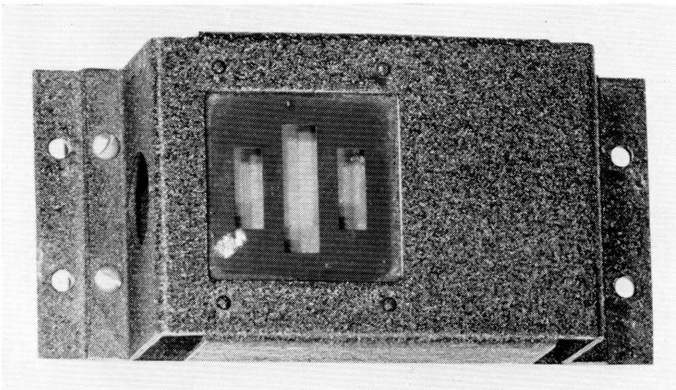

Figure 3 — Photoelectric Cell Assembly.

Operation

Basically, the operation of the Weston Light Integrator is rather simple. Referring to Figure 2, which is a very much simplified diagram, the operation is as follows:

Light from the arc lamp or other source illuminates the photoelectric cell, producing a photoelectric current which operates the integrating relay through the reversing relays. The latter reverse the direction of the photoelectric current through the integrating relay each time one of the integrating relay contacts is closed. This causes the integrating relay to oscillate back and forth between the stationary contacts as long as light is on the photoelectric cell. Each time the integrating relay contacts close, a pulse of direct current, which is obtained by means of a pair of vacuum tubes, energizes the multipole a-c motor causing it to advance a definite amount, independent of the duration of the current pulse. The motor, through a series of gears, advances the integrating dial until the black index is coincident with the red index on the manually operated dial, at which time the power relay is de-energized opening the lamp circuit and the photographic exposure is completed.

While the above explains the general principle, the operation of the photoelectric cell and integrating relay should be considered in a little more detail in order to understand how the actual measurement of light takes place.

The Photoelectric Cell

The photoelectric cell assembly shown in Figure 3 utilizes the same barrier-layer type of cell used in many other Weston photometric products. When light falls upon the photoelectric cell, current is generated which is directly proportional to the illumination; thus doubling the illumination doubles the photoelectric current. This photoelectric current is supplied to the integrating relay through a pair of reversing relays.

The Integrating Relay

The integrating relay is the heart of the Light Integrator. It is a permanent magnet, movable coil type of instrument similar to those used in d-c ammeters and voltmeters except that no springs are used to counteract the electrical torque of the movable coil. Current is conducted to and from the movable coil by means of filaments having no appreciable torque. When potential is applied to the movable coil, the resulting current causes the coil to move at an angular velocity where the emf generated by the movable coil is equal to the applied potential except for a slight loss necessary to overcome bearing friction. The coil velocity will, therefore, be proportional to the applied voltage, which in turn is proportional to the photoelectric current or the light on the photoelectric cell and consequently to the light on the copyboard or printing frame. Therefore, with high illumination, the integrating relay moves at a relatively high velocity and the integrating relay contacts are closed in rapid succession and, through the sequence previously explained, the motor-driven index becomes coincident with the manually operated index in a relatively short time. On the other hand, if the illumination is low, the integrating relay moves at a relatively slow angular velocity and the integrating relay contacts are closed in slow succession and consequently the motor-driven index requires a longer time to catch up with the manually operated index.

Operating Range

Light integrators are designed for operation between certain extremes of illumination and time. For the regular photo-mechanical applications, such as the control of light on the copyboard or printing frame, a complete set of ranges consisting of various combinations of light ranges and time limits are available. To determine the integrator range, it is necessary to know two things; (1) the range of time necessary to accomplish the exposures and (2)

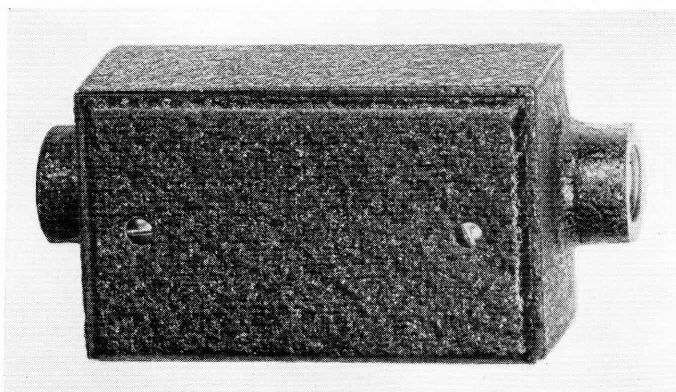

Figure 4—The Weston Model 9926 Auxiliary Relay.

the range of illumination necessary to accomplish the exposures. The time range is obviously known by the photographer but the illumination is seldom known. The simplest method of measuring the illumination is by means of a foot-candle meter, or if this is not available, a Weston Master Exposure Meter can be used. Place a white blotter or the back of a piece of white photographic paper where the cell will be located. Measure the reflected light in the same manner as a close-up reading is taken for photographic purposes. Multiply the reading obtained by four for the illumination in foot-candles or by 40 for the illumination in meter-candles.

Accessories

As previously stated, the integrator is designed for use on 120 volt-60 cycle circuits and if this is available and if the signalling device or electromagnetic pull-in coil on the arclight switch is wound for 120 volts-60 cycles, no accessories will be required. However, if the signalling device or electromagnetic pull-in coil is designed for a different voltage, such as 220 volts, then an auxiliary relay, such as the Weston Model 9926, Figure 4, must be used. If a 220 volt-60 cycle supply is available, a 100-200 watt step-down transformer must be used to operate the integrator. A Model 9926 Auxiliary Relay will also be required, as the integrator circuit is so arranged that it always delivers 120 volts-60 cycles to the signalling or control device.

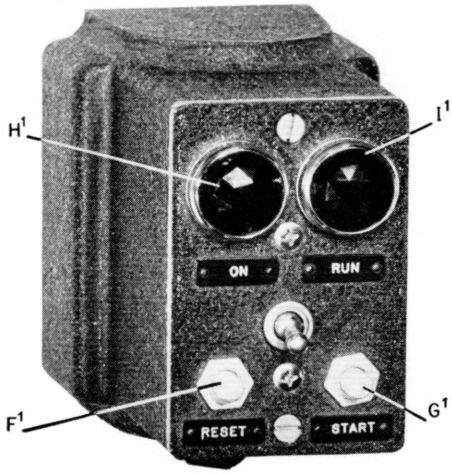

Figure 5—The Weston Model 9927 Remote Controller.

Remote Controller

In some photo-engraving shops, especially where repetitive exposures are necessary, the Weston Model 9927 Remote Controller, shown in Figure 5, will prove quite useful. A typical type of installation is where the light integrator is mounted in the camera room and the remote controller is mounted near the copyboard. By means of the remote controller, the integrator buttons (F) and (G) are duplicated by the buttons (F′) and (G′) on the remote controller and perform exactly the same functions. The pilot lights (H′) and (I′) are also duplicates of the integrator pilot lights (H) and (I).

Installation

Installation can readily be made by the average electrician, as wiring diagrams are furnished for both the integrator and accessories. Knock-outs are provided in the bottom of the case for both ½ and ¾-inch conduit connections and a liberal sized terminal block is contained within the case to facilitate electrical connections.

The photoelectric cell is contained in a metal case provided with two keyhole slots so that it can be either permanently or removably attached to the copyboard or the printing frame.

While the Model 807 Light Integrator is particularly adapted to the requirements of the photo-mechanical industry, it can readily be converted to integrate such associated quantities as X-rays, ultra-violet radiation and other portions of the spectrum by using a corrective filter on the photoelectric cell.

E. N.—No. 44 —*A. T. Williams*

Services for the Weston Engineering Laboratories

A prior article in ENGINEERING NOTES, *Volume II, No. 4, presented the general details of the new engineering-administration building and outlined briefly some of the more unique features of the construction. This article describes in detail the service accommodations which can be readily made available at any point within the building through the novel design of the wall chase.*

ENGINEERING laboratories are of many types: electrical, mechanical, chemical, electronic, physical testing, thermal, etc., and the service requirements of each are many and varied. The supplying of the various services required by the Weston Engineering Laboratories was recognized in the very early stages of planning the new Weston Engineering Building as a problem requiring special attention if the laboratories were to function efficiently.

An analysis of the requirements was made as well as a study of how other large companies had met similar requirements in their engineering buildings and although the service requirements of the Weston laboratories were similar to those of others, they were sufficiently different to require the development of a system of services to meet their own peculiar requirements. Further, any system developed would have to be such that all services could be extended to any and all parts of the building to meet future requirements.

The services required by the various laboratories are as follows:

1. Hot water (circulating)
2. Cold water
3. Drains for waste water
4. Air at 65-lb. pressure
5. Air at lower controllable pressures
6. Gas
7. A-C power up to several hundred amperes, 60 cycles
8. A-C power up to 20 amperes per phase, 60 cycles

9. A-C voltage, 120 volts, 60 cycles (regulated voltage)
10. D-C power, 120 volts, up to 20 amperes
11. D-C voltage, 160 volts (regulated voltage)
12. Three-wire signal lines to each laboratory
13. Three-phase, four-wire 120/208 volts
14. Three-phase, three-wire and ground 120/208 volts
15. Precision standardized 60 cycle line
16. Public address line
17. Telephone lines
18. Steam for heating
19. Microphone line
20. Additional services as required

The hot water, cold water, and gas are piped vertically through split beams at the center of the east wing to the second floor ceiling, from where they are run horizontally to the east, west and north wings. Laterals are run from these mains to the point of use.

The other services are all contained within the specially developed wall chase shown in Figures 1 and 2. This chase houses the radiators, two square electric ducts with openable covers, the air line, the water drains, and has special troughs for telephone and public address system wires and cables.

A special feature of this wall chase is the horizontal electric outlet panel which has provision so that utility outlets can readily be installed for the various electric services when and as required.

Air is available through the removable cover plate at each end of the electric panel.

The main front panel is easily removable by lifting it upward and forward, after which all ducts and piping are accessible for maintenance, repairs, and extension of the various services. The chase is continuous around the walls of the entire building on all floors except for the lavatories where the ends of the chase runs are connected by conduit. It is made of heavy-gauge steel reinforced to support 300-lb. loading. It is designed and fabricated on a six-foot module throughout. Each module of six feet houses a finned radiator with an insulated enclosure which acts as a chimney to produce circulation. Each radiator has individual automatic temperature control regulated by an adjustable modulating valve. The temperature-sensitive element which determines the amount of heat required by the radiator to maintain the desired pre-selected room temperature is mounted behind the air intake grill in the lower center of the removable panel. The cooler room air circulates by passing from the lower portion of the room through the intake grill, past the sensitive bulb, then by convection up past the radiator where it is heated and then out through the top grill to the room. Steam pressure from about three pounds to seven pounds is maintained in the steam risers at all times during the heating season. The knob for setting the pre-selected room temperature is located on top of the wall chase.

Since some of the laboratories do not require all of the services, only such services as were actually required were installed. Provision, however, was made so that any or all of the other services could be installed.

All electrical outlets of a specific type are always placed in the same relative location. As new ones are required, they are added in the allocated position. Ultimately, many of the panels will be supplied with all electrical services as it is not intended that any of the outlets be removed once they are installed.

Another feature of the wall chase from a design viewpoint is the two removable plates on the top surface just behind the air outlet plates. These two sectors were made removable to facilitate future vertical conduit runs or other piping as required without mutilating the chase itself. The smaller sections are removed and the necessary cutting performed by machine or hand tools in a workmanlike manner. If the small section is accidentally damaged in performing the cutting operation it can readily be replaced by a new one.

From the foregoing it can be seen that the wall chase plays a very important rôle in enabling the supplying of the multitude of services essential to the needs of the various laboratories. It renders a similar service to the office areas but to a lesser degree. It is pleasing in appearance as well as utilitarian in purpose.

E. N.—No. 45 —*F. X. Lamb*

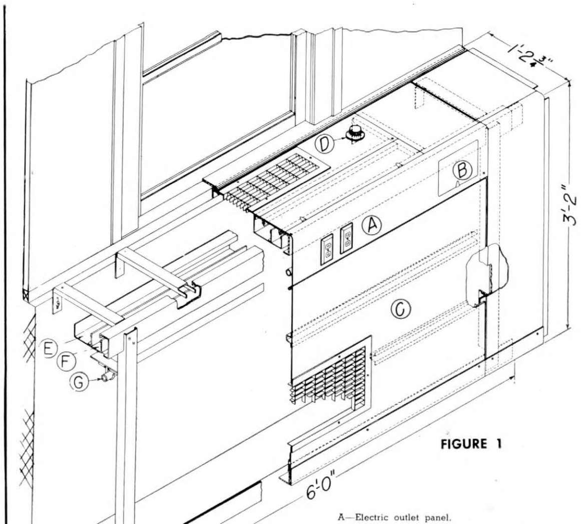

FIGURE 1

A—Electric outlet panel.
B—Removable cover plate for air connection.
C—Removable front panel.
D—Knob for setting desired room temperature.
E—Trough for telephone wires.
F—Trough for public address system wires.
G—Air line.

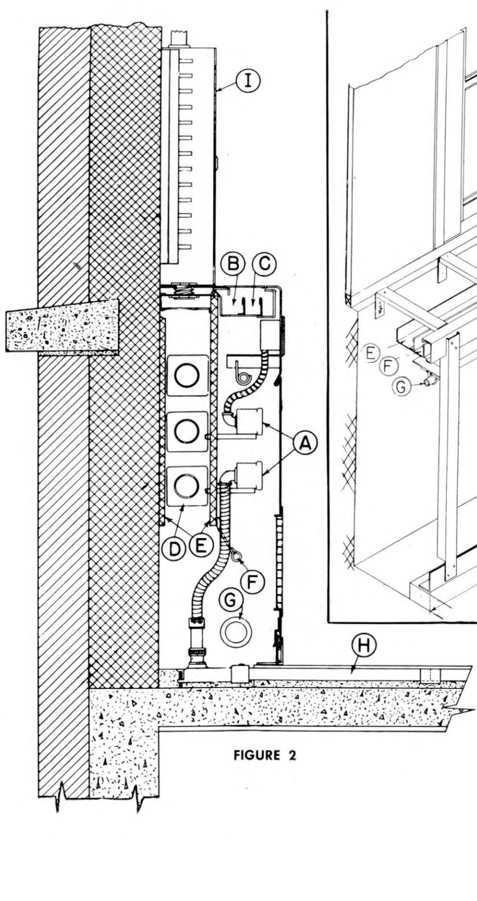

FIGURE 2

A—Electric square ducts, openable covers.
B—Trough for telephone wires.
C—Trough for public address system wires.
D—Finned radiators.
E—Insulation.
F—Temperature-sensitive element for temperature control.
G—Water drain.
H—Underfloor wire duct.
I—Telephone terminal box.