Chapter V

EXPERIMENTS

Many pages of words are sometimes not nearly so instructive as are little experiments which we perform for ourselves. When we see a thing happen, we understand it better Light units and the laws of light begin to mean something definite when we study the effect of voltage variation on light sources or apply the Inverse Square Law of illumination. Control lives for us when we actually control

That is the general idea underlying the experiments which follow Some of them will fit better into a Physical Optics course, others a straight Physics course or an Electrical Engineering course. The instructor naturally is the best judge of such things.

As to the equipment needed, it has been kept as restricted and inexpensive as practicable. Where Weston model numbers are mentioned, this is done solely because those specific instruments are the only ones entirely suitable for the job otherwise any instruments, accurate enough so as not to cloud the meaning of results, can be used.

The kits mentioned in the list following have been made up by Weston to furnish, as compactly and cheaply as possible, equipment needed to perform the experiments.

EQUIPMENT KITS

Kit No. 1—for Experiment Nos. 1, 3, 5, 9.

1 Weston Model 594 PHOTRONIC Cell
1 Weston Model 600 Microammeter (0-500)
1 UX Radio Tube socket
} Price $31.00

Fig 23. Model 594

Fig. 24. Model 600

Fig. 25. UX Socket

Kit No. 2—for Experiment Nos. 2, 4, 6, 7 8, 10.

1 Weston Model 614 Illumination Meter
1 Dust Filter (sprayed glass to give the equivalent effect of 1 month's dust on a lamp)
} Price $41.00

Fig. 26. Model 614

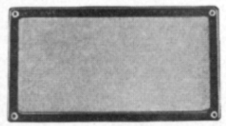

Fig. 27. Dust Filter

Kit No. 3—for Experiment Nos. 5, 9, 11.

1 Weston Model 634 Relay
1 Weston Model 705 Sensitrol Relay
1 Weston Model D-68690 Relay
} Price $47.00

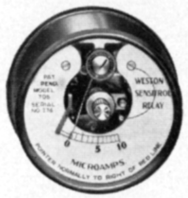

Fig. 28. Model 705

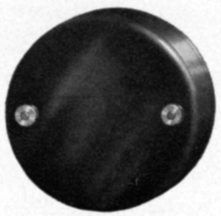

Fig. 29. Relay D-68690

Fig. 30. Model 634

PRICES SUBJECT TO CHANGE WITHOUT NOTICE

General Directions for Experimental Work

Experiments in a laboratory consist of two parts. The one is the actual performance of the experiment according to the directions given in the procedure for each experiment and the other is the report of the experiment in which a detailed account is given of apparatus employed, circuits used and results attained.

This report should be made on approved laboratory sheets or forms, should be done in ink or with typewriter, neatly and correctly, in its English and technical composition. It should be handed to the instructor at a certain time after the experiment has been performed, for his approval and credit. The art of precise technical description should be cultivated.

The *Object* of the experiment should be stated exactly in the report and should be kept constantly in mind during the whole of the work.

The *Apparatus* which is used for the first time in any experiment should be clearly described; for example, in the first experiment, the PHOTRONIC Cell should be described in considerable detail. Sketch its appearance. Tell of the operating principle as far as possible. *Meters* should be described as to their capacity, Maker, and maker's number, purpose and their scales illustrated by sketches. *Circuits* should be drawn in detail, showing supply lines, fuses, switches, meter connections and apparatus under test. This section of the report should be in such detail as to enable any one qualified to repeat the work of the writer of the report. The report should be written in the first person as the work of the single student without assistance from another. The *Procedure* should describe step by step, the operations performed to secure the results necessary to prove the object.

The *Questions* proposed should be repeated in the report and their answers given directly after each in turn. Tell the reason for your answer.

If Graphs are required to prove the object they should be made on uniform size paper with the report sheets proper, placing on each graph the table of ordinates or facts from which the graph was constructed.

The report should close with a *Conclusion* which should state the result of the work performed which should be in itself a confirmation of the object of the experiment.

Experiment No. 1

THE PHOTOELECTRIC EFFECT

OBJECT

To demonstrate that in PHOTRONIC Cells there is generation of direct electrical current by light waves. Or energy

APPARATUS

1—One Weston Model 594 PHOTRONIC Cell and mounting device (four-prong radio tube socket)
2—One (0-500) Microammeter with less than 100 ohms internal resistance.
3—One 100 watt tungsten lamp.
4—One lamp socket.
5—One fused switch and wires.

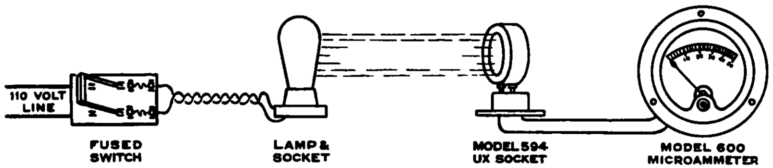

Fig. 31 Diagram of Apparatus

PROCEDURE

Set up the apparatus as shown in the diagram. When the connections have been checked and the fuses inserted, turn on the current supplying the lamp. If the meter shows a reverse reading on first trial, the connection between the Cell and the meter should be reversed. Place the PHOTRONIC Cell about 20 cm. from the light.

At this point the illumination should be about 350 foot-candles and the cell will generate in the neighborhood of 500 microamperes. If the meter shows an off-scale reading, then, of course, the cell must be moved farther from the lamp. The room should be darkened or the cell shielded from the natural illumination in the room. A pasteboard tube slipped over the cell provides a simple method of shielding.

When a position is finally chosen for the cell, record the reading indicated by the microammeter attached to it.

Then open the switch to the light and notice that the microammeter drops back to zero. Close the switch again and note that, the instant

the light is on, the cell supplies current to the meter again. Read and record the microammeter indication.

Now pass an opaque body (a piece of pasteboard between the light and the cell. Note that the cell responds to these interruptions as rapidly as the meter can follow

QUESTIONS

Did the cell produce sufficient current to be read on the instrument? Did it require the assistance of a battery or amplifier?

Does the current generated by the cell seem to indicate a chemical or physical change?

Does the same amount of light give the same microammeter reading each time? What does this indicate?

Is the current produced in the cell constant direct, variable direct or alternating, the light energy remaining constant? How would you prove it?

By what means could the current produced in this cell under the given lighting conditions be made to operate an audio transformer?

Can you list some applications for the photoelectric effect as manifested in the PHOTRONIC Cell?

Experiment No. 2

THE INVERSE SQUARE LAW

OBJECT

To prove experimentally that the illumination on an object (here the light target of the meter is inversely proportional to the square of the distance of the object from the light source.

APPARATUS

1—One optical bench.
2—One fused switch.
3—One 200 ohm—1 ampere rheostat.
4—One 0-150 volt voltmeter.
5—One 100 watt lamp.
6—One Model 614 foot-candle meter.

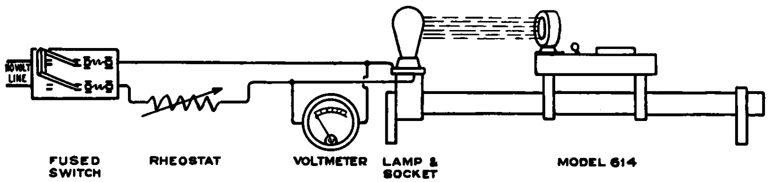

Fig. 32 Diagram of Apparatus

PROCEDURE

Set up the standard lamp on the optical bench as shown and replace the Bunsen photometer by a Model 614 Foot-Candle Meter Place the light target of the meter at a distance of about 20 cm. from the center of the light source and in a position perpendicular to the direction of the light beam. Select the 'high foot-candle range for a 100 watt lamp since at 20 cm. this will produce about 250 foot-candles. The 'high" medium or 'low' range on the Model 614 is selected by throwing the toggle switch to the corresponding marked position. When taking readings always use the range that gives a good readable deflection.

If the meter indicates anything before the lamp is lit, then the PHOTRONIC Cell is being affected by the natural light in the room. Usually the outfit can be turned in some way so as to exclude sufficient of this illumination to bring the meter to read zero. Otherwise the cell must be shielded in some way

After the connections have been approved, adjust the voltage on the lamp according to its rating.

Move the cell light target to a point 1 foot 30 5 cm. distant from the lamp. Record the reading. (How does this compare with the rating of the lamp?

Move the target of the meter 2 feet 61 cm. from the lamp and record the reading of the meter Note how the relationship of these two readings varies with the distance from the light source.

Now check your results by comparing a second set of readings taken with the light target placed at another set of distances from the lamp, one distance being twice the other

QUESTIONS

Do your readings check with the theoretical values of the Inverse Square Law? Try them with the formula for the law Here it is

$$E = K/d^2 \text{ or for this experiment,}$$

$$\text{Illumination in foot-candles} = \frac{\text{Lamp rating in candlepower}}{\text{Distance—(Feet}^2}$$

or, if the candlepower is not known, then compute Ed^2 which shall be a constant.

What is a foot-candle?

What light values are recommended for class-rooms, drafting rooms and passageways?

Why are individual lamps frequently used at each bench or work position?

Experiment No 3

EFFECT OF VOLTAGE VARIATION ON LIGHT SOURCES

OBJECT

To demonstrate how the intensity of light emitted by an incandescent lamp varies with the voltage across the terminals of the lamp. To construct a curve.

APPARATUS

1—One 100 watt tungsten lamp.
2—One variable rheostat having a resistance about equal to the resistance of the lamp.
3—One fused switch and connecting wires.
4—One voltmeter (0-150 volts)
5—One Model 594 PHOTRONIC Cell with a UX socket of the radio type in which it may be inserted.
6—One Model 600 Microammeter, range 500 microamperes, with connecting leads.
7—One sheet of graph paper ruled in centimeter squares.

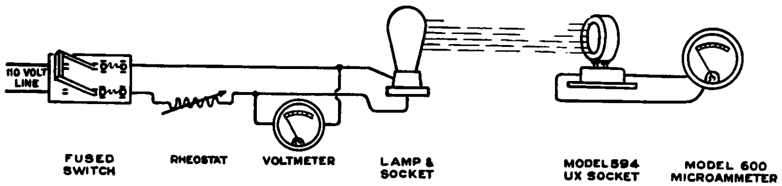

Fig. 33 Diagram of Apparatus

PROCEDURE

Connect the lamp to the supply circuit by means of a socket and switch which can be fused. Keep the switch open and unfused until all connections have been approved.

Across the terminals of the lamp place the voltmeter taking care to get the line polarity correct if direct current is used. It will be noted that the voltmeter as arranged, will measure only the voltage applied to the lamp, and not the total line potential nor the part used up in the rheostat. The rheostat is merely for controlling this lamp voltage.

Place the PHOTRONIC Cell about 12.7 cm. away from the lamp and, by its leads, connect it to the microammeter Then have the connections approved, fuse the switch and close it.

Adjust the rheostat so that the full line voltage appears on the voltmeter across the lamp. Move the cell closer or farther away until

nearly full-scale deflection of the microammeter is obtained. After the cell is fixed in position, read and record the microammeter divisions and the voltage on the lamp.

Then, by moving the rheostat slowly decrease the voltage on the lamp. Do this for successive voltages, so that about 6 steps are taken between the full line potential and the low limit reached when the whole resistance of the rheostat is in the circuit. With a 110 volt line this low point will be about 55 volts.

As each of these voltage steps is taken, read and record the divisions of the microammeter and the voltmeter indication.

PLOTTING THE CURVE

After recording all the readings, sufficient data have been acquired for the graph which may be made as follows

Use the lower left-hand corner of the graph sheet for the zero of both scales. On the vertical scale let each centimeter represent 10 volts. The total height of the graph, for 110 volts, will then be 11 centimeters and the low point, about 55 volts, will be approximately 5½ centimeters above the zero line.

For the horizontal scale, let one centimeter represent 5 divisions of the microammeter This will make the graph extend 10 centimeters to the right of zero for full-scale deflection.

Determine the points for the graph from the table of readings previously taken. After the points are marked in, draw a smooth curve through them. This should be possible if the experiment has been properly done.

CONCLUSION

The completed graph will show how the light produced by the lamp, as indicated by the current from the PHOTRONIC Cell, varied with the voltage applied to the lamp. Notice that the light energy does not fall and rise in the same way as the voltage does—equal voltage changes do not produce equal changes in current produced by the cell.

QUESTIONS

Why does the graph show a curved line?

What would a straight line have indicated?

At what level do voltage changes produce the largest changes in light emitted by the lamp?

Why is it important that the operating voltage of lamps be maintained at the proper rated value?

Experiment No. 4

MEASUREMENT OF CANDLEPOWER

OBJECT

To measure the candlepower of a 100 watt lamp.

APPARATUS

1—One optical bench.
2—One 100 watt lamp.
3—Two simple baffles for the lamp.
4—One Voltmeter, 0 to 150 volts.
5—One 200 ohm—1 ampere rheostat.
6—One Model 614 Illumination Meter.

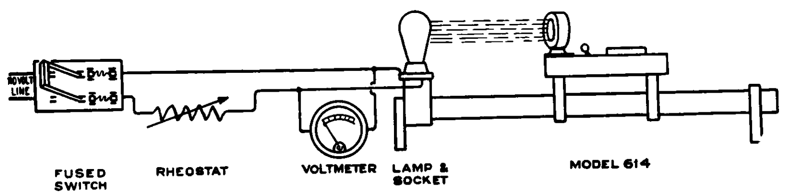

Fig. 34 Diagram of Apparatus

In this experiment we are going to standardize or measure the candlepower of an ordinary 100 watt lamp by means of a foot-candle or Illumination Meter

By using an Illumination Meter and applying the Inverse Square law we can establish the intensity or candlepower of a light source. The Inverse Square law see experiment No. 2 states that illumination is inversely proportional to the square of the distance from the light source.

Thus $$E = \frac{K}{d^2} \qquad \text{I}$$

in which E—represents the illumination in foot-candles
K—is the candlepower rating of the lamp
d—is the distance between the light source and the Cell, expressed in feet.

If we solve formula (I) for K we have $K = Ed^2$ (II

When the illumination in foot-candles is determined at a known distance from the light source we can solve for the candlepower rating of the lamp by the application of formula II

Suppose we find at a distance of 3 feet we have an illumination of 10 foot-candles as indicated by the illumination meter. Then by formula (II) we have

$$K = 10 \times 3^2 = 90 \text{ C.P}$$

PROCEDURE

Arrange the apparatus as indicated by the diagram and after the connections have been approved, insert the fuses.

Close the line switch and by means of the rheostat adjust the lamp voltage to its rated value.

Turn the cell of the Model 614 to its vertical position and move it close enough to the lamp to give a good readable deflection. Any one of the 3 foot-candle ranges, 'high' "medium or 'low' may be used by throwing the toggle switch to the desired range position. Record the indication of the illumination meter and the distance between the lamp and light target.

Baffles should be placed to shield the cell or light target so that it receives no reflected light from nearby walls or objects.

Repeat the operation by taking additional readings with the cell at various distances from the lamp and record a table as follows

Ft Candles	*Distance in Feet*	*Calculated (C.P Values of K*

Increase the applied voltage to the lamp 5 percent above its rated value and repeat the experiment in order to determine a new value of K.

QUESTIONS

A lamp in a lighting fixture 10 feet above the floor gives an illumination of ¾ of a foot-candle on the surface of the floor What is the candlepower rating of the lamp?

What will be the light intensity on the surface of a table 3 feet above the floor and directly beneath the fixture?

What effect does an increase in the rated voltage of a lamp have on the candlepower rating of the lamp?

Experiment No. 5

RELAY OPERATION BY A PHOTRONIC CELL

OBJECT

To show that a PHOTRONIC Cell can be used to operate a relay

APPARATUS

1—One 100 watt lamp.
2—One Model 600 Microammeter (0-500) with less than 100 ohms internal resistance.
3—One sensitive Relay Weston Model 634 (resistance about 300 ohms)
4—Connections.
5—One Model 594 PHOTRONIC Cell.
6—One fused switch.

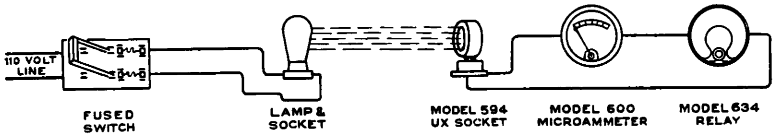

Fig 35 Diagram of Apparatus

THEORY OF A RELAY.

A sensitive relay as used in this experiment is an electrical device that operates on the same general principle as a d-c indicating instrument.

The function of a relay is to close a secondary circuit to do useful work when current flows in its primary circuit. The primary circuit consists of a moving coil in a magnetic field which carries a swinging arm, moving between two contact points. See Fig. 36

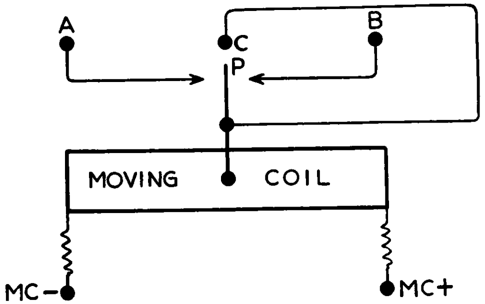

Fig. 36 Relay Diagram

Referring to Fig. 36 when a direct current flows in the moving coil connected to the terminals MC— and MC+ the coil will deflect to the right or left depending upon the polarity of the current. When the coil deflects it carries the contact arm P to contacts A or B, thus

closing the secondary circuits through AC or CB. The contact points on the swinging arm and the two contacts A and B are made of special material silver etc. to insure clean, perfect contact. When the current in the external circuit which is connected to AC or CB rises above a certain predetermined amount, sparking will occur at the contacts. This will cause them to be burned and they will lose their contact efficiency

PROCEDURE

Set up the apparatus as shown in the diagram, with the microammeter in series with the PHOTRONIC Cell and the Model 534 Relay In this way the meter will indicate the current needed to work the relay

Place the cell about 20 centimeters from the lamp. When all connections have been checked and fuses placed, turn on the lamp. If the distance between the cell and lamp is correct, the instrument should read in the neighborhood of 300 microamperes—provided the combined resistance of instrument and relay is not more than 350 ohms.

Notice that as soon as the light is turned on the relay snaps shut.

Now place a piece of pasteboard between the light and cell and move the light far enough away so that, when the pasteboard is removed, the relay does not close. Then slowly advance the lamp toward the cell until the point is reached where the cell delivers just enough current to close the relay

Read the current indicated by the microammeter when this happens. Notice that it is much less than the 300 or so microamperes used when the lamp was first turned on. Notice also that it is less than the current recommended for operating the relay

QUESTIONS

Is it very difficult for the PHOTRONIC Cell to operate a relay? Any kind of relay?

Is the Microammeter necessary for the operation of the relay?

Why are special metal contact points used in this relay? What other metals are similarly used?

What are the results of overloading the secondary circuit of a relay with respect to contact points?

How could this principle of photo-cell control of a relay be applied to control street lighting with respect to sunrise and sunset?

Name some other applications in which the action of a light beam, cell and relay system could be used

Experiment No. 6

DIRTY LAMPS AND REFLECTORS

Object

To show the effect of dirt on lamps and reflectors.

Apparatus

1—One optical bench.
2—One dust filter (sprayed glass to give the equivalent effect of one month's dust on a lamp)
3—One Model 614 Illumination Meter.
4—One Voltmeter (0-150 volts)
5—One fused switch.
6—One lamp holder.
7—One 100 watt lamp.
8—One lamp reflector.
9—One 200 ohm—1 ampere rheostat.

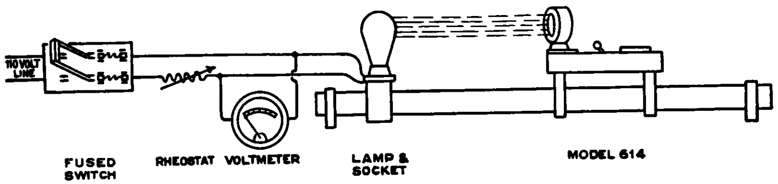

Fig. 37 Diagram of Apparatus

Procedure—Dirty Lamps

Set up the apparatus as shown in the diagram. Have all connections approved, then insert the fuses.

Mount a filter holder in a position between the target of the illumination meter and the light source or the filter may be held in the hand. Place a CLEAN 100 watt lamp in the lamp holder

When the lamp has been turned on, and adjusted to its rated voltage, move the light target toward the lamp until the meter reads say 300 on the "high' range of the meter Record this value. Caution—the voltage on the lamp should be maintained at a constant value throughout the experiment.

Insert the dust filter equivalent to about a month s accumulation of dust in its holder Notice how the illumination on the cell has been reduced, as indicated by the meter reading. Record the reading.

Procedure—Reflectors

To determine the effect of using a reflector over a lamp, use the same apparatus set up as used for testing dirty lamps. A clean 100 watt lamp should be used but without the dust filter

Turn on the lamp and read the number of foot-candles indicated by the meter.

Now place a clean reflector back of the lamp then note and record the meter reading.

Again place a dirty reflector back of the lamp and record the meter indication.

Questions—Dirty Lamps

What percent of the light emitted by the source, as indicated by the first reading, reaches the target after the dust filter is inserted?

What has become of the difference?

Will a dirty lamp have a similar effect? (Try it—take a reading using a dusty lamp. Clean it and make a second reading.) How do these readings compare with the first two taken?

Questions—Reflectors

Why are reflectors used with lamps?

What effect does a dirty reflector have?

What was the percentage gain in the light value due to the clean reflector? To the dirty reflector?

Is it important to keep lighting fixtures clean?

Experiment No. 7

EFFECT OF BURNED OR SMOKY LAMP

OBJECT

To show that much-used or smoky lamps cause waste by not giving as much light as new ones.

APPARATUS

1—One optical bench.
2—One fused switch.
3—Two 100 watt lamps of the same type —one quite old, one new
4—One Model 614 Illumination Meter.
5—One voltmeter (0-150 volts)
6—Connections.
7—One 200 ohm—1 ampere rheostat.

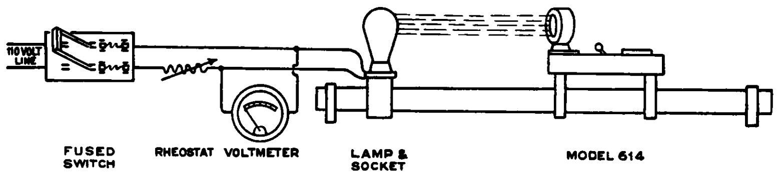

Fig. 38 Diagram of Apparatus

PROCEDURE

Set up the apparatus as shown by the diagram. Have all connections approved then insert the fuses.

Place the new 100 watt lamp in the lamp socket. When it is lighted adjust the voltage to the rated value of the lamp and see that this voltage is held constant throughout the experiment.

With the light target turned up in a vertical position move it close enough to the lamp to give a good readable deflection, using any one of three meter ranges desired. Note and record the meter indication.

Then, without moving the lamp socket or the target, replace the new bulb with the old one of the same wattage rating. After checking to see that the voltage on the lamp is still constant, read and record the indication of the illumination meter

In the same manner compare the illumination given by two new lamps of the same wattage, one clear and one frosted. Record these readings.

QUESTIONS

Why should a smoky lamp give out less light than a new one?

Taking the illumination obtained from the new lamp as 100% how much less light does the old lamp give?

Is there any economy in using lamps beyond their useful life or until they are nearly burned out?

Experiment No. 8

EFFECT OF DIFFERENT WALL COLORS

OBJECT

To show that the color of a wall has considerable effect on the amount of usable light in a room.

APPARATUS

1—One Model 614 Foot-Candle Meter.
2—One 100 watt lamp with a reflector.
3—One blackboard.
4—One light blue sheet }
5—One buff sheet } paper may be used.
6—One white sheet }

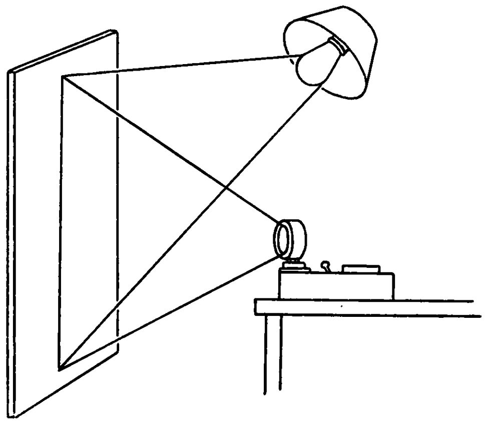

Fig. 39 Diagram of Apparatus

PROCEDURE

In testing the effect of wall color upon room illumination, we are really testing comparative reflecting power Set up the apparatus as shown by the diagram so as to cause light from a lamp to fall upon the blackboard or sheets, and then use the foot-candle meter to measure the amount of light reflected.

Direct the light from a 100 watt lamp upon the blackboard. Place a reflector over the lamp so that its rays are all directed toward the board and none reaches the target of the foot-candle meter except by reflection. Then hang the white sheet over the blackboard.

Place the foot-candle meter in such a position that it receives the light reflected from the white sheet. Move the meter to such a distance that it indicates an intensity of 5 foot-candles, using the 'low' range of the Model 614 Record this reading.

Then, without changing the position of the lamp or the foot-candle meter replace the white sheet with the pale blue sheet, then the buff sheet. Then remove the sheets and use the bare blackboard. Record the amount of light reflected in each case.

Notice that the white sheet reflects much more light than the blackboard, also that tinted surfaces such as pale blue and buff have good reflecting power

QUESTIONS

What percent increases in illumination were effected by substituting the light surfaces for the black one?

Why are the interiors of photographic dark rooms painted black?

Why are the ceilings of halls lighted by indirect illumination usually painted with light tints?

Why is it desirable to keep walls and ceilings clean by washing them occasionally?

Experiment No. 9

MAGNETIC COUNTING

OBJECT

To demonstrate the simplicity of an industrial control system.

APPARATUS

1—One 100 watt lamp.
2—One Model 594 PHOTRONIC Cell.
3—One Model 634 Sensitive Relay (resistance about 300 ohms)
4—One magnetic counter and its supply source.
5—One small power relay (D-68690)
6—One fused switch.
7—Connections.
8—One 4½ volt Battery

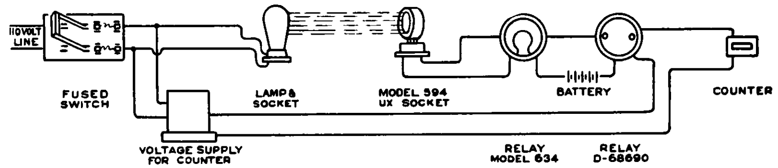

Fig. 40 Diagram of Apparatus

PROCEDURE

In this experiment, the current generated by a PHOTRONIC Cell will be used to 'trip' a sensitive relay When this sensitive relay operates, it will close a secondary circuit through the coil of the power relay Thus energized, the power relay will snap shut and close its secondary circuit which will then energize the magnetic counter

This is the usual sort of chain employed in industrial control work where the small current from a PHOTRONIC Cell is used to control devices that require comparatively large wattage for their operation.

Notice the function of the two relays they amplify" by acting as mechanical switches. The sensitive relay is a switch for the power relay and that acts as a switch for the counter Each device has its own power supply The sensitive relay current from the cell the power relay a 4½ volt battery the magnetic counter whatever voltage supply its manufacturer designates.

Set up the apparatus as shown in the diagram. Have all connections approved and then insert fuses.

The coil of the sensitive relay is in series with the PHOTRONIC Cell. The relay's secondary circuit, the fixed and moving contact, is in series with the coil of the power relay and the 4½ volt battery The fixed and moving contacts of the power relay are in series with the magnetic counter and whatever power source the counter requires.

Place the PHOTRONIC Cell about 20 centimeters from the lamp. At that distance, when the light is turned on, the cell will generate sufficient current to operate the sensitive relay properly

Turn the light on. Notice that the sensitive relay operates immediately and is followed in quick succession by the power relay and the magnetic counter.

Break the light beam a number of times by inserting a piece of cardboard between the cell and the lamp. Every time the light is cut off the sensitive and power relays open. As soon as the cardboard is removed the original cycle is repeated. Notice that the magnetic counter keeps track of the number of interruptions.

The Sensitive relay used in the Commercial form of Weston Photronic Counter relay is much faster in action than the Model 634

QUESTIONS

The current from the PHOTRONIC Cell could be amplified by vacuum tubes so as to work the counter Would this method be more or less reliable than the relay chain ? Would it be more or less complicated?

What are the advantages of magnetic counters over mechanical ones using levers, arms, etc.?

Can you devise a system whereby the chain, as set up, could be used to sort packages of two different heights?

Suggest an arrangement whereby boxes of different colors might be placed in separate bins automatically the boxes coming in an endless succession on a conveyor.

Experiment No. 10

LABORATORY LIGHT SURVEY

OBJECT

To survey the lighting conditions in the laboratory

APPARATUS

1—One Model 614 Foot-Candle Meter.

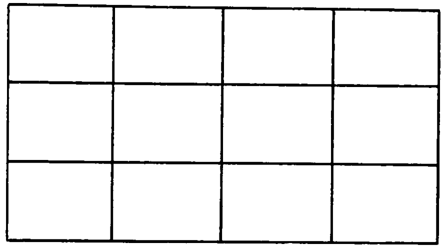

Fig 41 Diagram of Room

PROCEDURE

The laboratory should be spaced off as shown in the diagram.

At the center of every unit space make a measurement of the light intensity by means of the foot-candle meter For all measurements have the meter at the same distance from the floor—say bench level. Care should be taken to stand in such a position that the body will not reflect light on the target or prevent a portion of the light from reaching the target.

Make two surveys, one for daylight illumination with all lamps turned off and one for artificial illumination with shades drawn to exclude the daylight.

Light intensities, as follows, are accepted as adequate for particular tasks. For reading normal print 10 to 20 foot-candles. For reading fine print or sewing 20 to 30 foot-candles. For severe visual work 30 to 50 foot-candles. Less than 10 foot-candles is inadequate for critical seeing.

QUESTIONS

Is the daylight level of illumination adequate for the various tasks done at different places in the room?

Is the artificial level of illumination adequate at all locations in the room?

Suggest changes or rearrangements to better the present conditions. For daylight illumination. For artificial illumination.

Make a table showing the amount of light needed for ten seeing tasks, purposes or occupations.

Experiment No. 11

OBJECT

To demonstrate the use of a PHOTRONIC cell for comparative density measurements.

APPARATUS

1—One 100 watt lamp.
2—One fused switch.
3—One Model 705 Sensitrol Relay
4—One power relay (D-68690)
5—One lamp—indicator or pilot.
6—One Model 594 PHOTRONIC cell.
7—One smoke chamber.
8—One 4½ volt battery
9—One 3 volt battery
10—One electric bell.

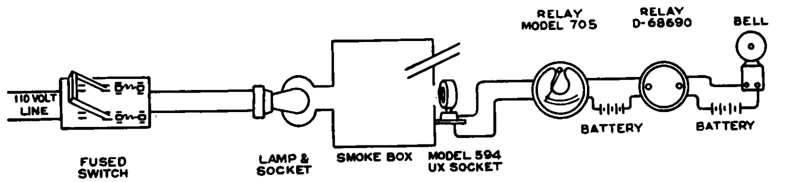

Fig. 42 Diagram of Apparatus

PROCEDURE

Set up the apparatus as shown in the diagram. Have all connections approved and then insert fuses.

In the other experiments, where relays were used, their contacts closed when the current flowing through the coil MOUNTED to a certain value. In this experiment the reverse will be the case the Sensitrol relay described on page 40 will snap shut when the current from the PHOTRONIC cell becomes LESS than some predetermined value. To have the relay operate in the desired direction it must be set properly The method of doing this will be explained farther on.

We are going to make a 'Smoke Alarm Our smoke chamber any sort of box that will hold the cell and lamp mounted at opposite sides, will represent a miniature smoke stack. We shall so arrange things that, when the stack is clear the Sensitrol relay will remain open as soon as smoke is blown into it however the relay pointer will begin to swing over toward the fixed contact. When the smoke reaches a certain density the relay will snap shut, activate the power relay and this latter will cause the electric bell to ring.

The Sensitrol Relay will operate directly from the PHOTRONIC cell. When it closes, its contacts will serve to close the circuit which includes the coil of the power relay and a 4½ volt battery When the power relay closes, its contacts will close the bell circuit thru the three volt battery

Our outfit requires setting first of all. To do this, proceed as follows Temporarily replace the PHOTRONIC cell with a foot-candle meter and adjust the lamp which furnishes light for the cell so that it will give an illumination of about 15 foot-candles. Then put the cell back in its original position in the stack'

The Sensitrol relay must now be adjusted so that the pointer swings AWAY from the fixed contact when light in excess of 15 foot-candles reaches the cell. This involves setting the zero adjuster' and also seeing to it that the relay current has the proper polarity

After the light source has been adjusted to about 15 foot-candles and the cell is back in the stack' free the relay pointer from the magnetic fixed contact by means of the re-set knob on the glass front. If the polarity is correct, the pointer will remain away from this contact. If this does not happen, then reverse the leads to the relay

When the pointer is swinging free, with the light at 15 foot-candles turn the zero adjuster" until the pointer just comes within the field of the fixed contact and the relay snaps shut. In this way the 'zero' of the relay has been made to be the point represented by the current generated in the cell with 15 foot-candles illumination. If greater illumination reaches the cell after this, the relay will remain open when the light falls, the pointer will swing toward the fixed contact and the relay will close when it reaches the 15 foot-candle mark.

After the relay has been adjusted, increase the light to some value above 15 foot-candles, say 25 free the pointer by means of the re-set and allow it to swing up the scale.

When the pointer swings free and the relay remains open, start blowing smoke into the stack' using a glass tube or straw

Notice that, as soon as the smoke begins to come between the cell and the light, the pointer immediately starts to swing toward the fixed contact. It gets closer and closer as the density of the smoke increases until finally the smoke is so dense that the light on the cell falls below 15 foot-candles. Due to the way the relay has been set, as soon as this happens, the rider on the pointer comes within the field of the magnetic contact and is attracted up to it.

When contact is thus effected, the Sensitrol relay closes the power relay circuit whereupon the alarm bell signals its warning.

To repeat the experiment it is simply necessary to clear the stack' of smoke and re-set the Sensitrol so as to free the pointer from the fixed contact. Then re-introduce the smoke and the cycle will be gone through again.

If for any reason smoke is objectionable, the system as set up can be made to operate by using colored solutions such as potassium permanganate, etc. A glass receptacle is substituted for the smoke chamber and the cell and light source mounted on either side, so that the cell views the light after it passes through the solution.

The initial setting for 15 foot-candles is made with clear solution and then the light intensity is raised to the 25 foot-candle level. After the relay has been set, the permanganate is stirred in until the density becomes such that the relay closes.

Of course the 15 foot-candle and the 25 foot-candle values are arbitrary and any other values may be chosen so long as the cell furnishes sufficient current to operate the Sensitrol relay

QUESTIONS

State the advantage of a smoke alarm or other density control device?

Suggest a way to automatically re-set the Sensitrol Relay after the density level of the smoke returns to normal ?

Name some places where density control is important?

Chapter 6

SUGGESTIONS FOR PROPER INSTRUMENT USE

1—Level the instrument and check the zero adjustment before use.

2—If the instrument is not magnetically shielded, test it for the presence of stray magnetic fields by turning it through an angle of 90° The reading should be the same in each position.

3—In dry weather instruments frequently collect an electrostatic charge which can be removed by breathing on the glass.

4—Be mindful of the polarity of direct current instruments. They should be connected in the circuit in such a way that the current flows through them in the proper direction.

5—Do not place instruments too closely together

6—Avoid reading the instrument at an angle. To insure against this, wherever possible, use instruments whose scales are mirror-backed. In such meters the eye can line up the pointer with its mirrored image when readings are being made.

7—Eliminate reading error' by choosing an instrument which gives an indication well up on the scale. For instance A scale such as is shown in the figure has 100 divisions.

Assume that the instrument has a guaranteed accuracy of 1% According to the standards set by the American Institute of Electrical Engineers, this means that the instrument may be off calibration one division at any point on the scale.

Obviously at full scale, one division off represents an inaccuracy of one percent. The same discrepancy at 10 on the scale means an error of 10% Therefore, whenever possible, use only the upper half of the scale.

8—Keep all contacts clean. A small amount of dirt, especially in current circuits, can introduce sizable errors.

9—Standard instruments should be protected as much as possible against excessive vibration.

10—For accurate work the case of the instrument should be tapped lightly so as to be sure there is no friction between the pivots and the jewels and that the pointer swings freely in response to current through the movement.

Chapter 7

BIBLIOGRAPHY

COMPLETE BOOKS

"PHOTO-ELECTRIC PHENOMENA —*Hughes & DuBridge* (McGraw Hill Pub. Co.)

"PHOTO-ELECTRIC CELL APPLICATIONS"—*Walker & Lance* (Sir Isaac Pitman & Sons)

"PHOTO CELLS & THEIR APPLICATION"—*Zworyken & Wilson* John Wiley & Sons)

"THE SELENIUM CELL, ITS PROPERTIES & APPLICATIONS'—*G. P Barnard* (Richard R. Smith)

"LIGHTING CALCULATIONS'—*H H Higbie* John Wiley & Sons)

"PHYSICAL OPTICS"—*R. W Wood* (The MacMillan Co.)

PHOTOELECTRICITY—*Allen, H S* (Longmans, Green & Co.)

PHOTOELECTRIC CELLS—*Campbell & Ritchie* (Pitman & Sons)

PHOTOELECTRIC CELLS & THEIR APPLICATIONS—*John S. Anderson, Editor*

REFERENCES

1 EDMOND BECQUEREL.
Comptes Rendu Hebdomadaires des séances de l Académie des Sciences. Paris 9 144,561 (1839)

2. WILLOUGHBY SMITH.
"The Action of Light on Selenium."
Journal of Telegraph Engineers, 2-PP 31 33 (1873)
Nature, 7-P 303 (1873)
American Journal of Science, series 3-5 P 301 (1873)

3 M. L. SALE.
"The Action of Light on the Electrical Resistance of Selenium."
Proceedings of the Royal Society 21) 283 285 (1873)
The London, Edinburgh & Dublin Philosophical Magazine & Journal of Science, series 4-P 47 (1874)
Nature, 8 P-134 (1873)

4 L. P ROSSE (4th Earl)
"On the Electrical Resistance of Selenium."
The London, Edinburgh & Dublin Philosophical Magazine & Journal of Science, 47—P 161 169 (1874)
American Journal of Science, series 3 17 PP 512-513 (1874)

5 H. HERTZ.
Annalen der Physik, 31—P 983 (1887)

6. WILHELM HALLWACKS.
Annalen der Physik, 33 P 301 (1888)

7 ELSTER & GEITEL.
Annalen der Physik, 38 P 497 (1889) 41 P 161 (1890)

8. W G. ADAMS & R. E. DAY
"Action of Light on Selenium."
Philosophical Transactions of the Royal Society 167 P 313 349 (1877)
Proceedings of the Royal Society 25 P 113 117 (1876)
The London, Edinburgh & Dublin Philosophical Magazine & Journal of Science, series 5 3 PP 295 300 (1877)

9 C. E. FRITTS.
"On a new form of Selenium Cell and Some Electrical Discoveries made by its Use."
Proceedings of the American Association for the Advancement of Science 33 PP 97 108 (1883

10. L. O. GRONDAHL.
Science, 36 P 306 (1926)
Review of Modern Physics, 5 P 141 (1933)

11 THE ELECTRIC EYE, Acousto-lite Corp.

12. THE PHOTOLYTIC CELL, H. L. Halterman, S.B.

13 COMPARATIVE CHARACTERISTICS OF THE COPPER OXIDE AND PHOTRONIC CELLS, Chas. H. Bartlett. Rev Scientific Insts., Vol. 3 No. 10, October, 1932.

14 NOTES ON THE PHOTRONIC CELL, B. P Romain. Rev Scientific Instruments, Vol. 4 p. 83 1933.

15 THE PHOTRONIC ILLUMINATION METER, W N Goodwin, Jr., Trans. Illuminating Engineering Soc., Vol. 27 No. 9 Dec. 1932.

16. THE PHOTRONIC PHOTOGRAPHIC EXPOSURE METER, Jour. Soc. Motion Picture Engineers, W N. Goodwin, Jr., Vol. 20, No. 2, PP 95 118, (1933)

17 PHOTRONIC CELL, A DIRECT AID TO BETTER LIGHTING, Anthony H. Lamb, Electrical World, April 16, 1932.

18. FREE ELECTRICITY WHILE THE SUN SHINES, Anthony H. Lamb, Instruments, Oct. 1932.

19 ELECTRIC EYES WATCH OVER THE POWER PLANT Anthony H. Lamb, Power Plant Eng., July 1933

20. A TWO INCH POWER PLANT W E. I. Corp., Maintenance Engineering, Apr. 1932.