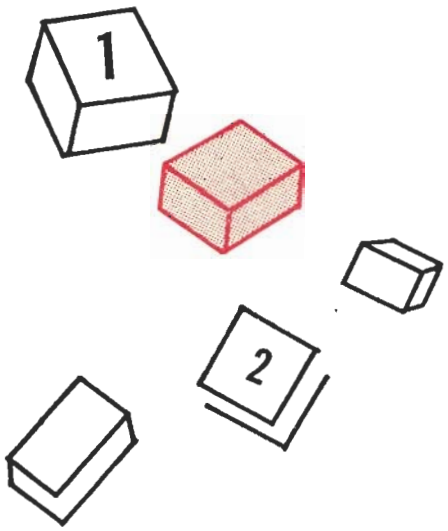
Industry controls warns indicates counts PHOTOELECTRICALLY



By ALLAN LYTEL

MANY control systems rely on photoelectric cells for an efficient job. For example, they often handle the otherwise difficult task of counting products on a conveyor belt. Since a photocell or phototube can detect objects that have odd shapes, they simplify the counting process. Then, too, photoelectric counters are much faster than mechanical types and require less maintenance.

Fig. 1 shows a dual-purpose system. It indicates the number of large and small packages and counts the total number. Two photoelectric counters do the job. The one in the low position (on the left) counts all the boxes. The other counter is set so it counts only the high boxes. The low boxes pass under its light beam and not through it. By subtracting the number of large boxes from the total, you get the number of small boxes. Similar arrangements can be used to count three sizes of containers.

Fig. 2 shows a control system often used where packages are filled from a hopper. The feed to the hopper is usually continuous and at a steady rate. However, if the filling line should slow down or stop, the hopper can overflow, wasting material. The photoelectric control shown prevents this. Whenever the level in the hopper blocks the light beam, the feed is cut off.

Another variation of this type of system is shown in Fig. 3. Here, a motor-driven conveyor delivers boxes to a weighing station. However, the weighing station cannot handle the boxes as rapidly as the conveyor delivers them. To solve this problem a photocell is set up so it stops the conveyor whenever a box breaks the light beam. This triggers an electronic timer that restarts the belt after a suitable interval. The belt runs until another box breaks the light beam, and so on.

Photoelectric relay circuits

Sometimes operating speed is not im-

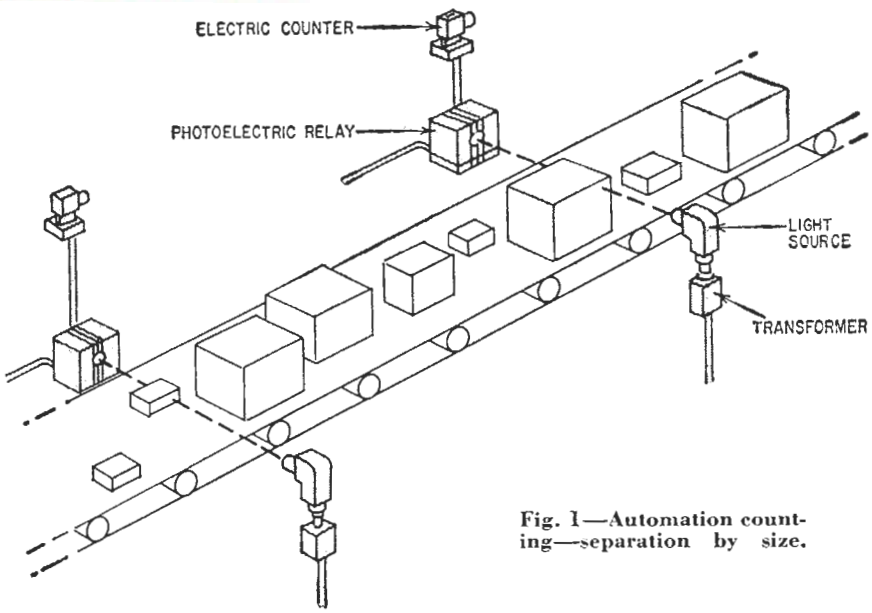


Fig. 1—Automation counting—separation by size.

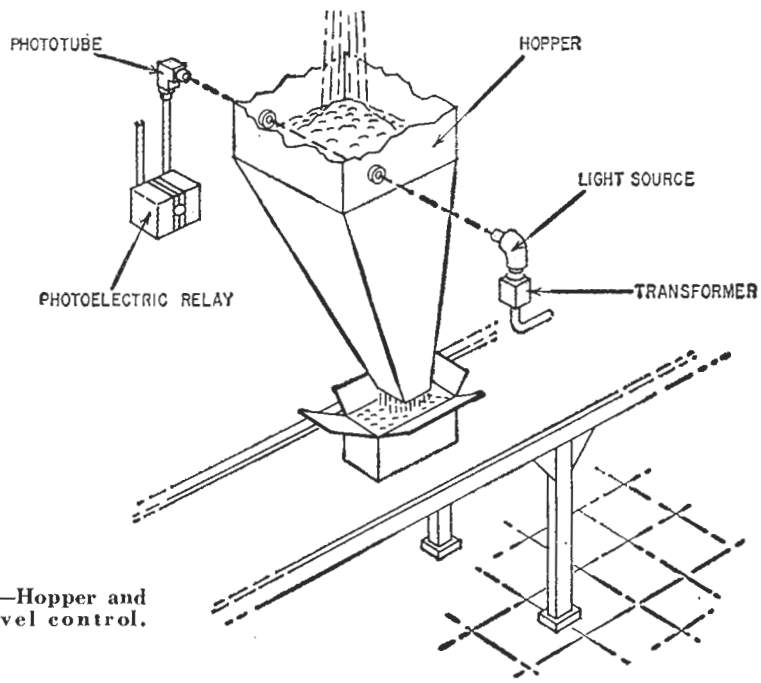


Fig. 2—Hopper and bin level control.

portant and 60-cycle ac can be used for the phototube and amplifier plate supply. With an ac supply they conduct only while their plates are positive. While such an arrangement is inexpensive, it has drawbacks. A tube with self-rectifier action is going from conduction to cutoff 60 times a second. For low-speed operation this is satisfactory, but for high-speed operation dc plate supplies are used.

Fig. 4 shows a circuit designed for speeds up to 1,200 operations a minute. It is not high-speed in a radio sense but, if the device is counting packing cases on a conveyer belt, 1,200 a minute is very fast.

The unit's power supply uses a 6X4 as a half-wave rectifier. Note that the power transformer's two primaries can be tied in parallel for 117-volt or in series for 230–250-volt operation.

Relay RY1 (operating relay) in series with the 5AQ5 plate is energized when light falls on the 1P40 phototube. With 75 volts across the 1P40 and a 10-megohm load a steady small current flows while light falls on the cathode. The drop across the load makes the phototube's cathode positive—it is tied to the control grid of the pentode through a 1-megohm resistor.

A voltage divider (6,000, 3,000, and 1,200 ohms) is also across the 75-volt line. A sensitivity control, the 3,000-ohn potentiometer, adjusts the positive cathode voltages. When the light beam is interrupted, the 1P40 stops conducting and positive grid voltage is removed. Because of the positive cathode voltage, pentode plate current is reduced and plate relay RY1 opens.

There are a number of safety features in this circuit. A failure in either the light source, the rectifier tube or its associated circuit, or the amplifier tube will open the plate relay. If the control is being used as a safety device, the fail-safe feature is important since failure of the control will not go unnoticed. A second relay (RY2) is another safety device. It energizes after the circuit is warmed up. It de-energizes if the phototube goes off or the amplifier tube fails. Relay contacts are wired in series so if either relay opens the controlled device is cut off.

Examples of uses for this relay are in Figs. 5, 6 and 7. In Fig. 5 a photoelectric control is used as a hand guard. If the operator's hands interrupt the light beam, the machine will not operate. In this application, phototube or light-source failure must stop the machine. **Photoelectric devices alone are not recommended for safety protection since they can be fooled or tricked.**

An automatic system for photographing book pages is illustrated in Fig. 6. When the page reaches the stop, it breaks the light beam and actuates the camera. Note that the beam is focused so it is very narrow where the page hits it, assuring accurate operation.

A carton sorter is shown in Fig. 7. Different register marks are used on the cartons. A register mark is a printed area used for photoelectric control because of the way the light beam reflects from it. In this example there are cartons with two types of register marks, high and low, as well as no marks. All cartons move along the main conveyor belt from right to left. At the first station, cartons with low register marks actuate the control which pushes these cartons onto the first side conveyor. Cartons with high register marks are pushed off onto the second side conveyor by the second control station. Unmarked cartons continue down the main conveyor.

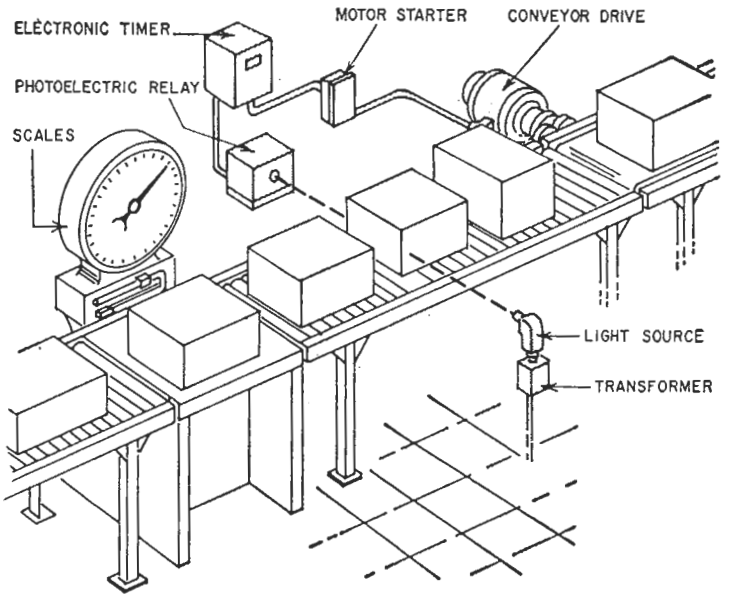
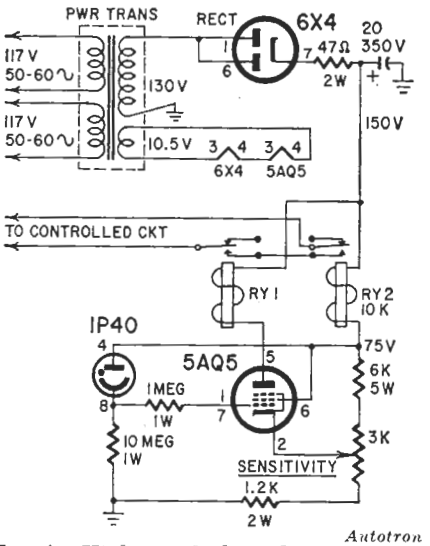


Fig. 3—Conveyor feed control.



Autotron

Fig. 4—High-speed photoelectric circuit handles up to 1,200 operations per minute.

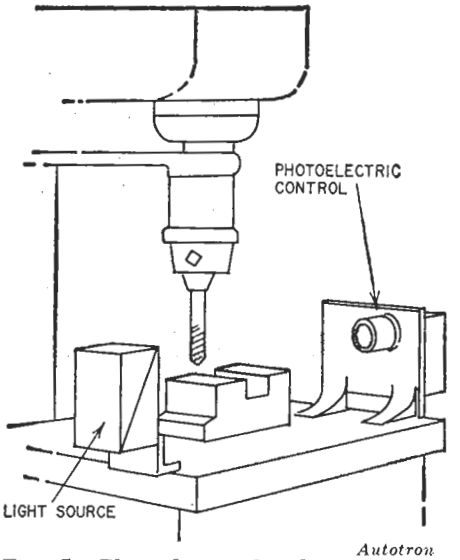


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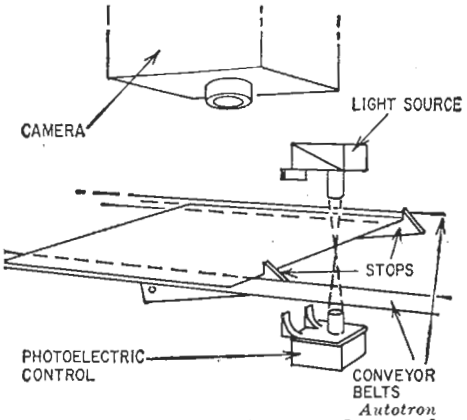
Fig. 5—Photoelectric hand guard for dangerous machinery.



Autotron

Fig. 6—Automatic photographing of book pages.

Modulated-light relays

Photoelectric devices are often used outdoors. An ordinary light source would have to be very bright to operate a photoelectric relay in direct sunlight, but a modulated light beam overcomes this problem.

Fig. 8 is the circuit of the G-E CR7505-BI00G3 modulated-light relay. It works like a radio receiver. A phototube (V1) is connected to two R-C-coupled amplifiers. The 6SH7 has a tuned plate circuit which responds only to the desired modulated light. A diode detector (V4-a) feeds the output stage (V4-b) which drives relay RY in its plate circuit.

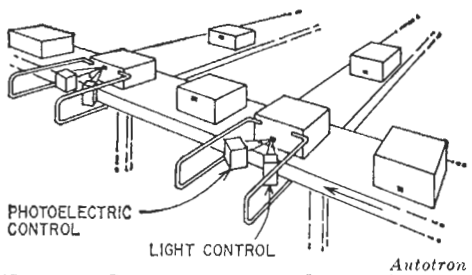


Fig. 7—Sorting cartons by register marks.

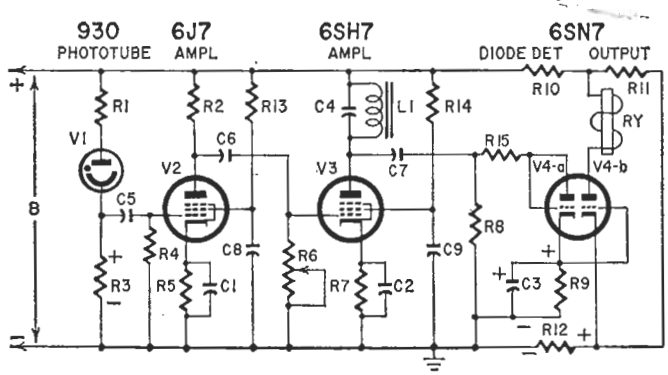
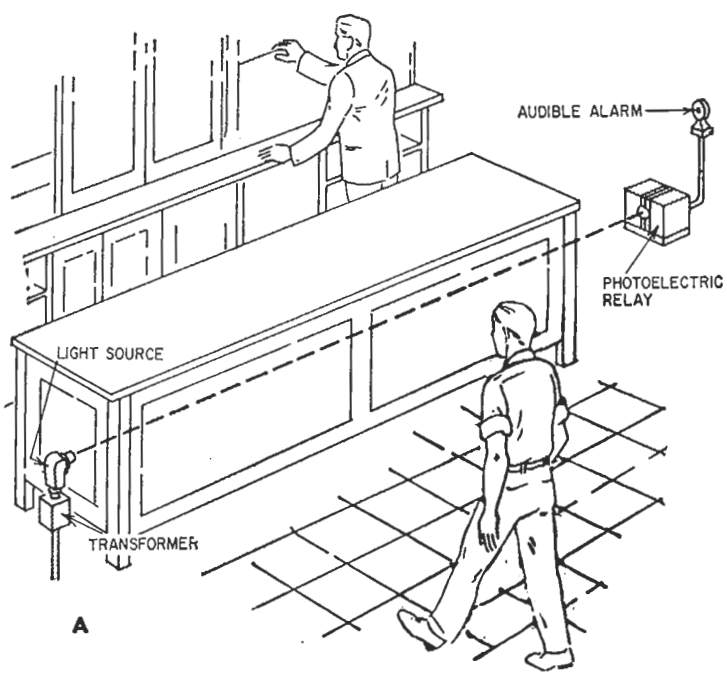


Fig. 8—Circuit of a General-Electric modulated-light relay.

Light falling on its cathode causes the phototube to draw current, but steady light, or slowly changing light intensity, will not pass through the ac amplifiers because of the coupling capacitors. But the light source for this relay is chopped by a rotating disk—is interrupted about 900 times per second. This is the system's carrier. The chopped light causes a series of dc pulses through R3, R1 and the phototube. There is a current pulse for each light segment at the 900-cycle rate. These pulses are coupled to the 6J7 control grid. Their polarity across R3 is positive, as indicated, and they appear at the 6J7 as an ac signal. The amplified signal is applied to the 6SH7 but, because of the resonant plate load (C4, L1), only signals of the desired frequency are amplified.

V4-a is connected as a diode detector. Current flow from cathode to plate creates a voltage drop across R9 so the cathode is above ground. This positive voltage is directly coupled to the grid of the output tube (V4-b). There is a positive voltage on V4-b's cathode from R12, which is part of a voltage divider across the supply voltage. Without any received signal there is no detection, no drop across R9, and V4-b's grid is at ground. This keeps V4-b cut off when no signal is being received, when steady unmodulated light is received or when the beam of modulated light is interrupted at a rate other than 900 cycles.

The proper signal, however, drives V4-b's grid positive enough to overcome the cathode bias and the tube conducts, closing relay RY. If the modulated beam is interrupted (even for 0.1 second), V4-a stops the detecting action since it no longer receives an ac signal. C3 discharges through R9,



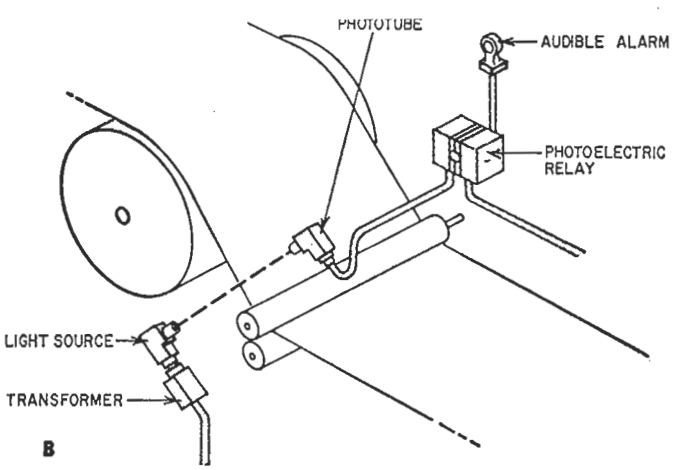
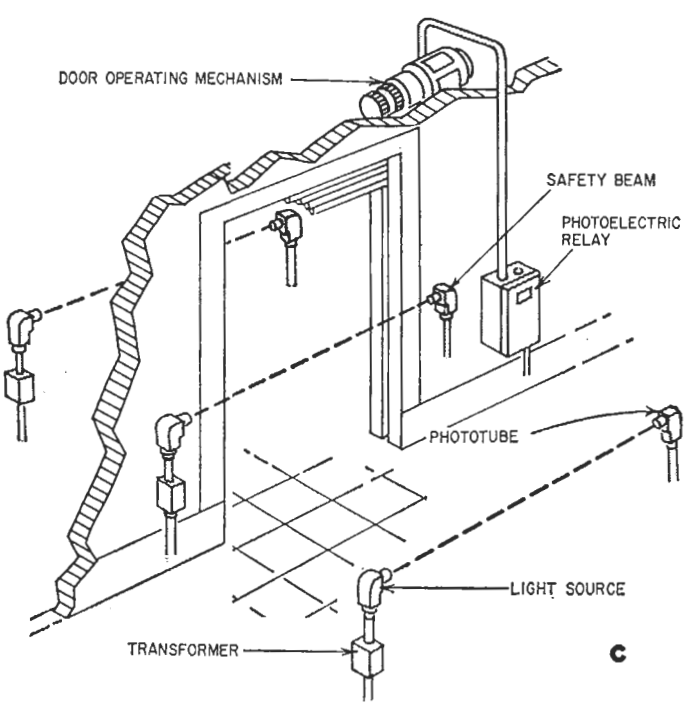


Fig. 9—(Left) Sales-counter installation indicates approaching customers. (Below) Door opener is triggered by vehicles or people approaching from either side. (Lower left) Web break detector stops machine if there is a break in the material feed.



making V4-b's grid negative in a grid-leak action. As soon as V4-b is cut off, relay RY opens and gives an alarm through an external circuit.

A modulated-light relay can operate in daylight over distances up to 1,000 feet. Sunlight must not be focused on the phototube cathode or it will be destroyed. Such equipment can protect outdoor installations against intruders.

Three ways of using such controls are shown in Fig. 9. A sales-counter application is shown in Fig. 9-a. A photoelectric relay and buzzer automatically signals the approach of a customer. Each counter can have its own signal system.

In Fig. 9-b an automatic overhead door opener is shown. As a person or vehicle approaches the door (from either direction) the interrupted beam of light operates a relay that controls the door opening mechanism. A safety beam in the door frame keeps the door from closing until the vehicle clears the doorway.

An automatic break detector is shown in Fig. 9-c. A break in the roll or web trips an alarm and can also stop the machine. There are many other more complex control systems for machines which use long rolls of material but this type is a simple alarm or safety device.

Service and maintenance

To prevent shutdowns, a regularly scheduled program of preventive maintenance is required. At least once every month:

- Dust the lenses with a clean, soft cloth.
- Check the lineup between the light source and the phototube holder. (The light-source lamps have an expected life of about 1,000 hours at 5.2 volts and 3,000 hours at 4.8 volts.)

The following routine is suggested for servicing:

1. Inspect the light source for burned-out lamps.
2. To determine if the trouble is in the control panel or the phototube, disconnect the phototube connections and touch a jumper momentarily between the terminals to which the phototube anode and cathode connections were made. If the relay operates, the fault is not in the panel. Replace the phototube and check its connections for continuity and leakage. With the phototube removed, resistance between phototube leads should be about 1,000 megohms; resistance between the leads and ground should be greater than 100 megohms.
3. If the relay fails to operate in step 2:

- Check for power on the incoming line by measuring the voltage at the incoming terminals.
- Replace the tube.
- Check the three transformer secondary voltages and the one dc voltage shown on the diagram.

Smoke detection

Photoelectric control of smoke from industrial furnaces is becoming increasingly important. The General Electric CR7505-R201 is a smoke-density indicating unit. Because black smoke absorbs light, the amplified phototube current can be read directly on a milliammeter calibrated in "smoke density." This is true for black smoke only. Local ordinances must be considered and taken into account when calibrating the equipment. When the preset value is reached, a thyratron is triggered which trips an alarm.

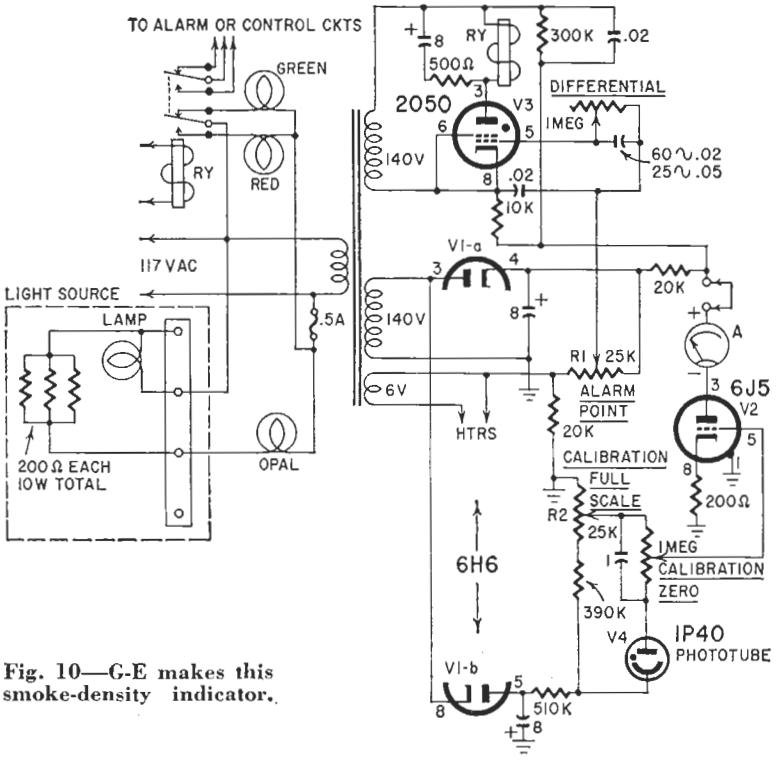


Fig. 10—G-E makes this smoke-density indicator.

The unit's circuit is shown in Fig. 10. Half-wave rectifiers are used. The negative supply is used for the phototube (V4). The positive supply goes to the 6J5 amplifier. The 2050 thyratron has an ac plate supply which is one of the power transformer secondaries. Control R1 sets the value to trigger the alarm. Control R2 is a calibration for the indicator meter.

High-speed, high-sensitivity controls

In applications where both high speed and high sensitivity are needed, the CR7505-N210-N211-N212 relays can handle up to 600 counts a minute with a relay or up to 1,000 counts a minute with a dc counter or fast operating load in plate output circuit.

A 6SJ7 voltage amplifier and a 6V6 power amplifier provide great sensitivity (Fig. 11). A 6H6 rectifier supplies the voltage amplifier and the

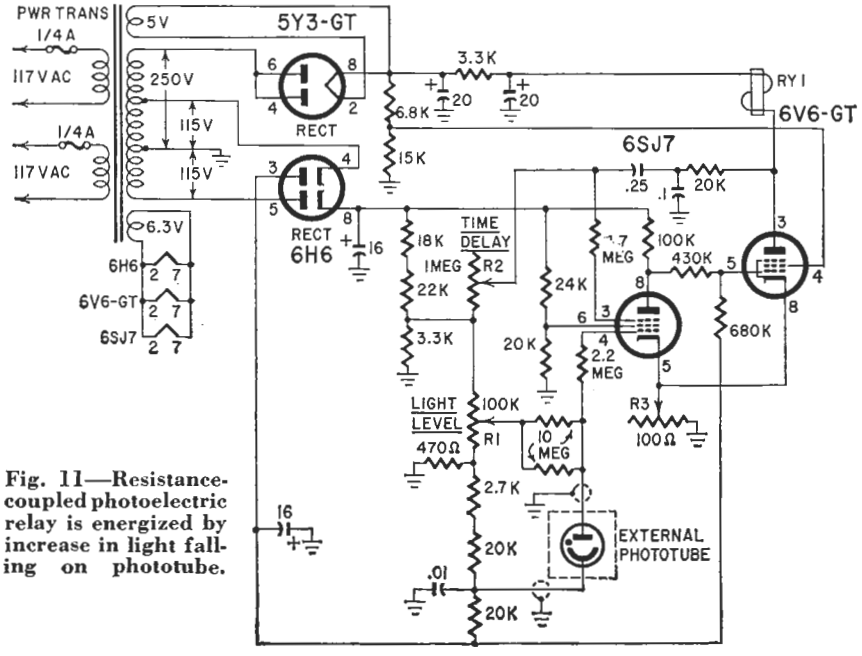


Fig. 11—Resistance-coupled photoelectric relay is energized by increase in light falling on phototube.

phototube. A separate 5Y3-GT, with its plates tied, is the power amplifier plate supply. Three adjustable controls are provided. R1 adjusts the amount of light required to actuate relay RY1. R2 adjusts the length of time the relay remains energized after it is turned on by the power amplifier. R3 adjusts the difference between the relay pickup (energized state) and dropout (de-energized state).

The circuit is direct-coupled from the phototube to the voltage amplifier and from the voltage amplifier to the power tube. It energizes the light relay on a light increase. Because of the direct coupling, the circuit responds to slow changes in light level which appear as low-frequency signals. By using capacitive coupling, the same circuit can be made responsive to only rapid changes in light intensity.

After the light source and phototube holder are properly aligned and focused, the LIGHT LEVEL control must be properly set for successful operation, using the following procedure:

A. For capacitive coupling:

1. Turn the LIGHT LEVEL knob (R1) completely clockwise.

2. Make and break the light beam at the source, using the same percent of cutoff that will normally occur. If the light is reflected, provide the normal signal repetitively.

3. Rotate the LIGHT LEVEL knob slowly counterclockwise until the relay starts operating. Note this position.

4. Continue rotating the LIGHT LEVEL knob counterclockwise until the relay stops operating. Note this position.

5. These positions should be separated by at least two divisions for consistent operation. The proper setting is halfway between these positions.

If the proper adjustments cannot be obtained despite proper alignment and focusing of the light beam, proceed as follows:

a. If the relay does not follow the light-source flashes or if there is insufficient difference between the positions found in steps 3 and 4, apply flashes by covering and uncovering the phototube lens. If the relay works now, ambient light must be reduced or an aperture must be placed inside the phototube holder to reduce the total light reaching the phototube.

b. If response is still off, recheck the aim, focus, distance and cleanliness of optical parts. Check connections and replace the phototube. If no response is obtained, follow the instructions provided by the manufacturer.

B. For resistive coupling:

Resistive coupling should not be used outdoors unless necessary. If it is used, ambient light must be excluded.

Repeat the first four steps above.

5. Make and break the light beam at the phototube lens. The relay will probably start operating again. Continue rotating the LIGHT LEVEL knob counterclockwise until the relay stops operating. Note this position.

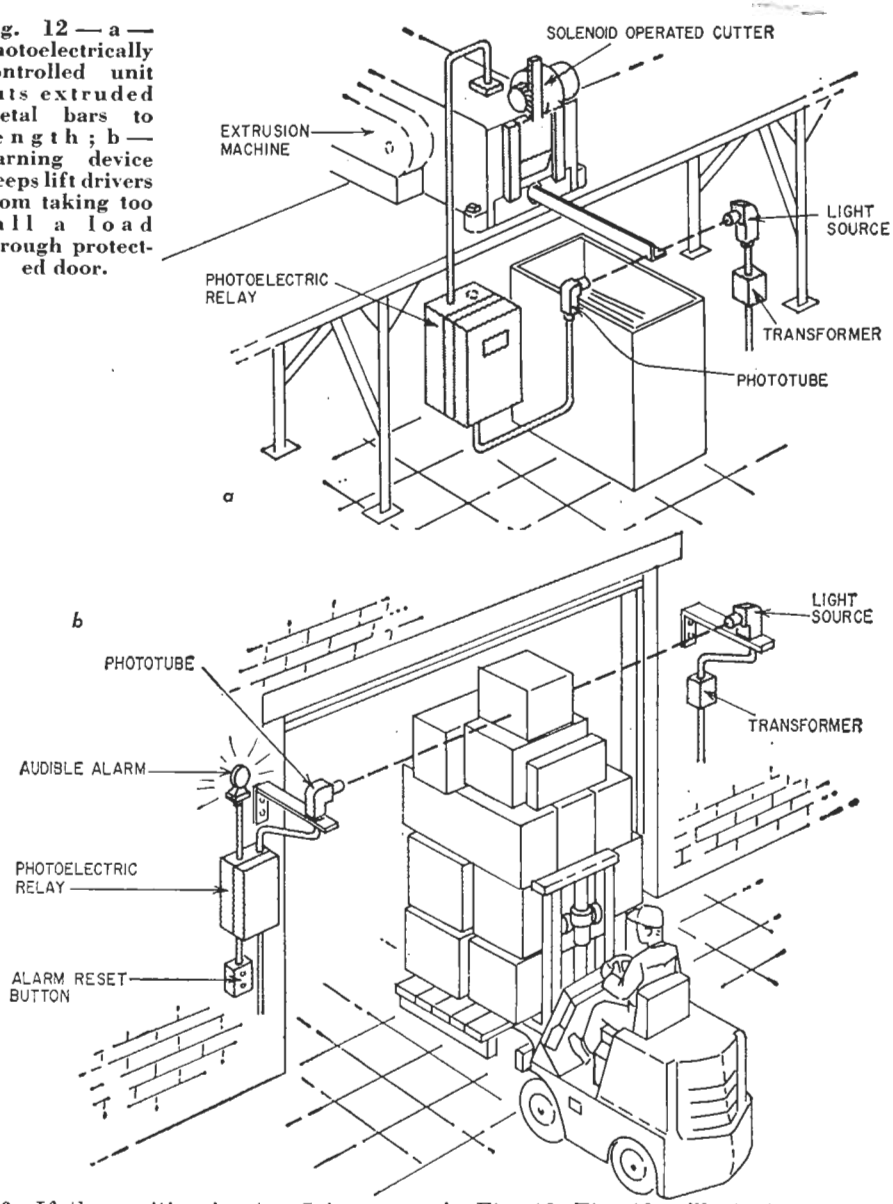


Fig. 12 — a — photoelectrically controlled unit cuts extruded metal bars to length; b — warning device keeps lift drivers from taking too tall a load through protected door.

6. If the position in step 5 is more than one numbered division from the position in step 4, there is too much ambient light and it should be decreased.

7. If the position in step 4 is less than three numbered divisions from the position in step 3, there is insufficient change in illumination. If these positions are less than 5 on the dial, increase the sensitivity by disconnecting one of the 10-megohm resistors between R1 (LIGHT LEVEL control) and the phototube.

8. If the position in step 4 is above 7 on the dial, it can be brought into better range by masking off part of the phototube lens.

C. Relay differential adjustment:

This control does not normally require readjustment. But if the magnetic relay chatters (which may occur after the tubes are changed), the control (R3) should be turned clockwise just beyond the point where chattering stops. This increases the voltage differential between pickup and dropout.

Two uses for these relays are shown in Fig. 12. Fig. 12-a illustrates a control that automatically signals a cutting mechanism when the proper length of material protrudes from the machine. The device triggers the cutoff mechanism. As the extruded material leaves the press and breaks the light beam, the photoelectric relay energizes the cutoff mechanism. Tolerances of 1/16 inch may be held by providing a mask in front of both the phototube and light source with a 1/16-inch wide slit.

Fig. 12-b is a safety overheight signal. When a lift truck approaches with a load which will not clear a doorway or overhead conveyor, the light beam is interrupted and the alarm sounds. The alarm will continue to sound until the reset button is pushed. The equipment may be used indoors and will detect objects 1½ inch in diameter or larger traveling at speeds up to 10 miles an hour.

As we have seen, photoelectric controls perform many industrial duties. Knowing how they work and the differences between the various types is the first step toward keeping them operating properly. **END**