PHOTOELECTRIC REGISTER CONTROLS ...how they work

Cutting, punching, imprinting, and embossing are vital parts of many industries and the electronic controls that keep these devices working accurately can become a profitable source of income for the aggressive independent service shop

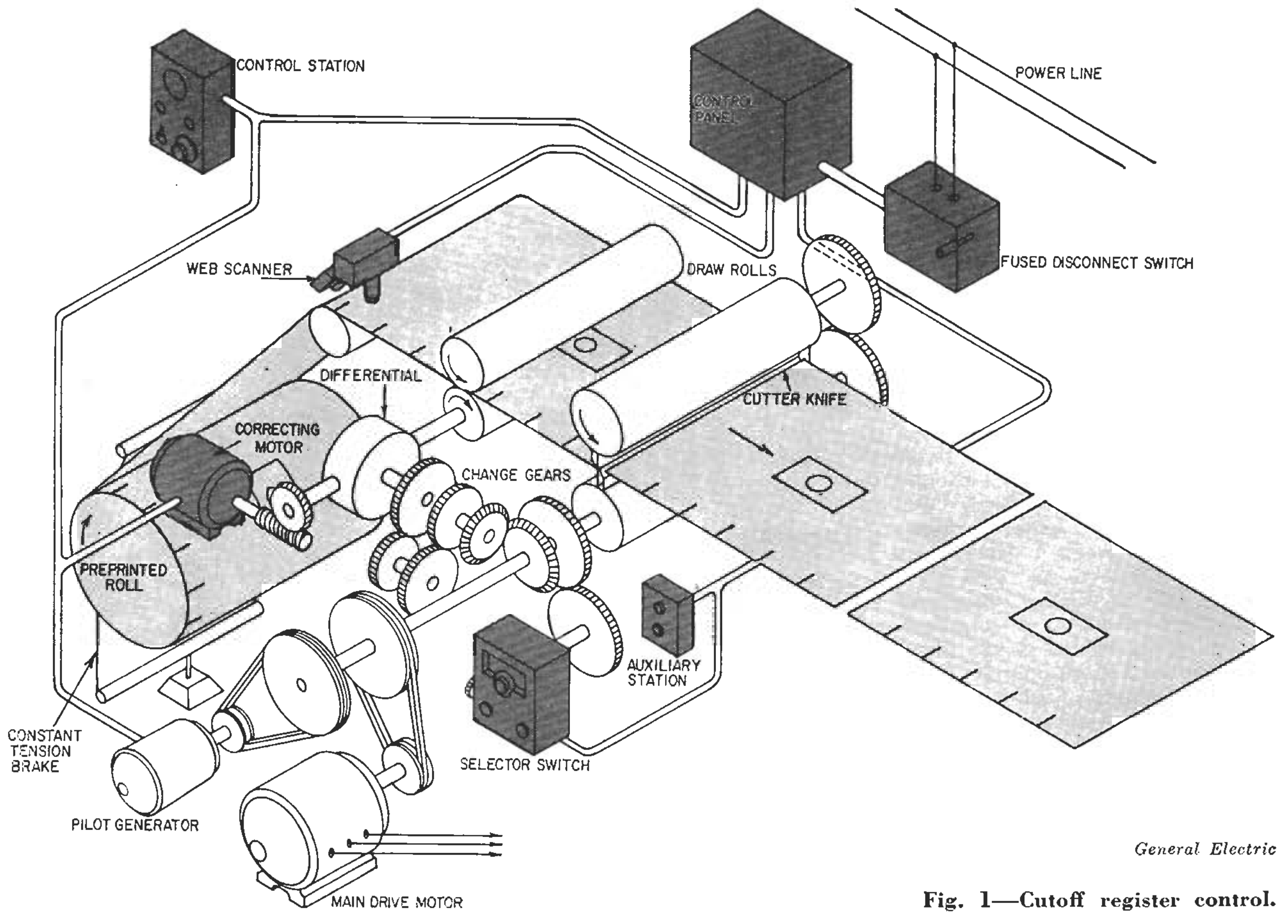
By **ALLAN LYTEL**

WHEREVER rolls of material are cut to sheet size, imprinted, punched or embossed—whether in a steel mill, a paper plant or a printing house—photoelectric controls make sure the cuts, printing, holes or embossing come out in the right place.

Wherever a continuous strip of material (or *web*) is wound into a roll, photoelectric controls help keep the roll's edges smooth and even. These electronic devices can be and are kept in good working order by electronic technicians. Any technician can repair or maintain one of these systems if he knows how it works. Let's examine some of the types that are in use.

A correction type of register control made by G-E is shown in Fig. 1. It is used on a cutting machine and requires a roll of paper (or other material) preprinted with register marks that trigger the web scanner controlling the cutter knife. Each cut produces a sheet of paper of the proper length. The system has built-in correction to compensate for errors in the machine or changes in the roll or web caused by stretching or shrinking.

This may seem foolishly complex but there is more to the cutting than you might think. Suppose the machine were cutting pages from a preprinted web—a seemingly uncritical operation. What difference does an error of .01 inch in



General Electric

Fig. 1—Cutoff register control.

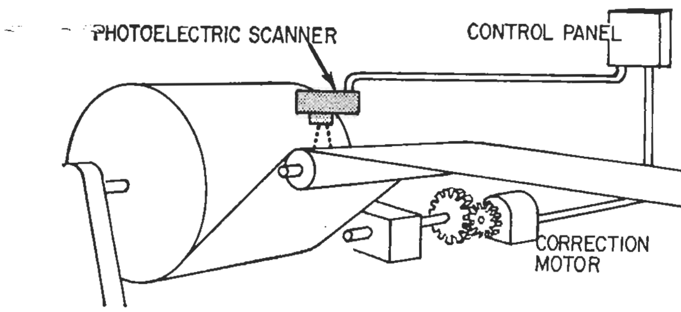
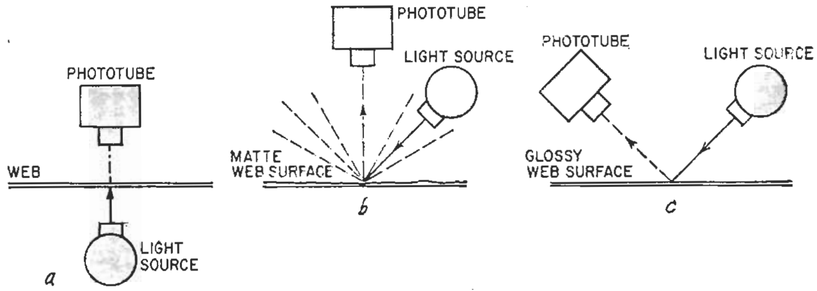


Fig. 2—Basic operation of G-E side register control systems.

Fig. 3—Three light-source and phototube-pickup arrangements; a—transmitted light scanning; b—diffuse reflected light scanning; c—specular reflected light scannning.



a 3-foot length of paper make? None, if you are cutting only a couple of sheets. But when many thousands of pieces are cut, and the error is cumulative, you have a 1-inch error after 100 pages and an error of 10 inches after only 1,000 pieces. Before you know it you are cutting the page in the middle instead of at the end.

The error control system does four things:

- The web scanner detects the relative position of the register marks.
- The selector switch detects the relative position of the cutter blade.
- The control panel circuitry compares these positions to determine their relationship.
- The correcting motor adjusts for any difference between the actual and the proper cutting position.

Side register controls

In operations such as paper printing or slitting, you end up with improper printing and wasted materials if the web moves sideways. Some system for keeping the paper in line is needed.

Such a system is shown in Fig. 2. The edges of the web are "seen" by a photoelectric tube which controls the web's side-to-side movement. The controls can be at the beginning of the process (where the web enters the machine), at the end of the process (where the web leaves it) or at some intermediate point.

To control sideways motion, a web scanner is needed. Such scanners fall into two groups—static and dynamic. The static scanner "watches" the web's edge and produces a steady signal to indicate the position of the web at all times. A dynamic scanner produces a signal only when a register mark passes the light beam. Dynamic scanners are commonly used as cutoff register controls to cut material to proper lengths.

Light can be transmitted through the web, as in Fig. 3-a, or reflected in a diffused manner, as in Fig. 3-b, where the surface is rough, or scanning can be specular as in Fig. 3-c.

The light source includes a lens system to focus the light on the desired position. The phototube is set to pick up the desired light according to the type of scanning. Phototubes are made with several color sensitivities, but the most important two for register controls are the red-sensitive S-1 and the

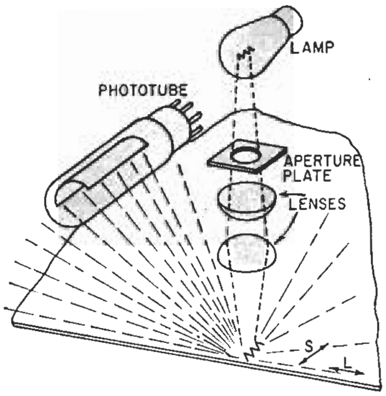


Fig. 4—Simple optical system for small photoelectric web scanners.

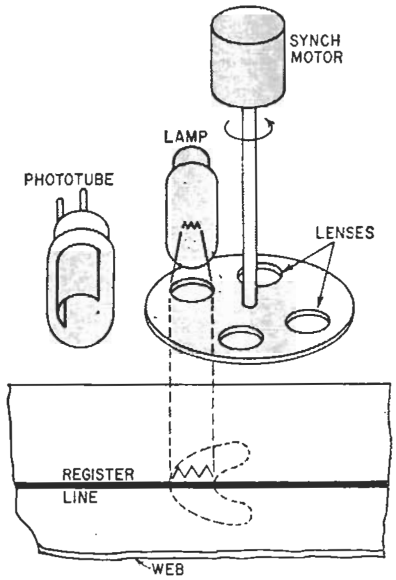


Fig. 5—Rotary lens web scanner.

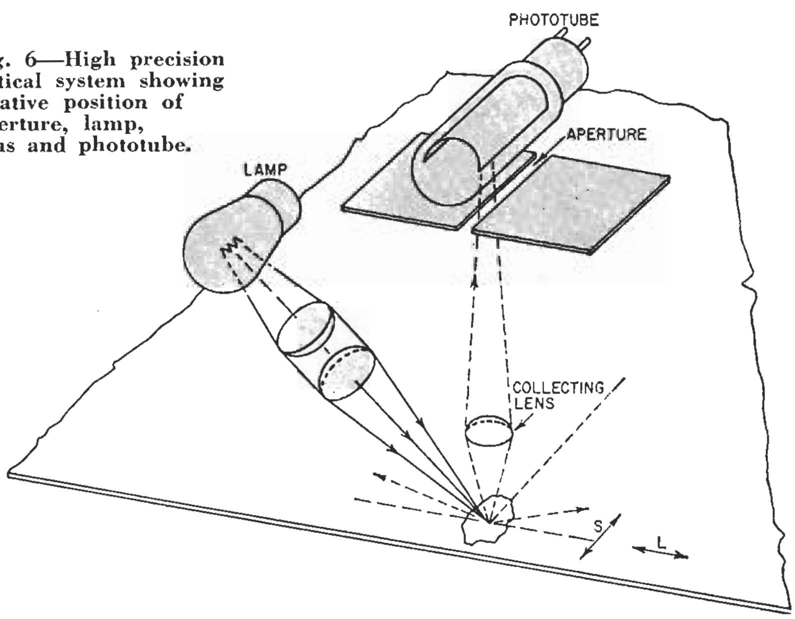


Fig. 6—High precision optical system showing relative position of aperture, lamp, lens and phototube.

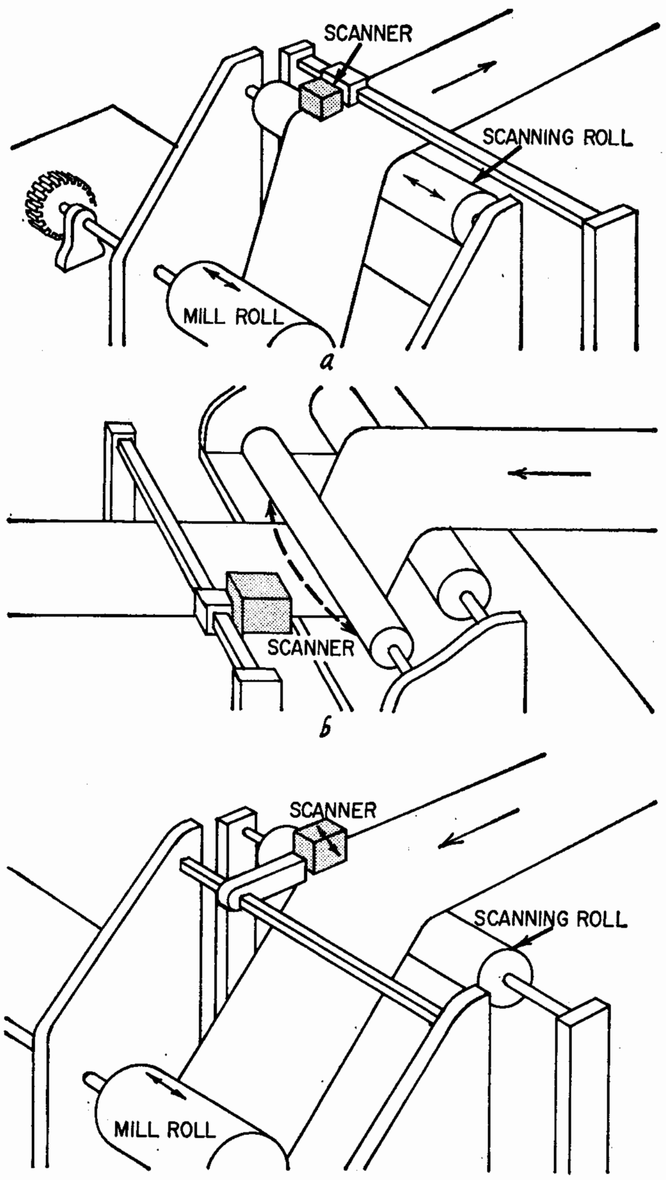


Fig. 7—Three kinds of side register controls: a—pay-off—for guiding a web entering a processing machine; b—mid-line—for guiding a web in the middle of a processing line; c—wind-up—for guiding a web at the exit end of a processing machine.

blue-sensitive S-4. These types include the red-sensitive 930, 868/PJ23 and the blue-sensitive IP39, 934 and 441. The preferred, most sensitive types are the IP40, 927, 918 and 927 (red) and 5581, 5583 and IP37 (blue).

The simple optical system used in the General Electric 3S7515-PS102 is shown in Fig. 4. The phototube is placed as close to the web as possible. As the web moves, scanning can be either sidewise (S) or lengthwise (L).

In the more complex system of Fig. 5, a rotary lens system does the scanning. A spot image from the light source is swept across the register line. The pulse from the phototube is phase-compared with the driving signal for the synchronous motor. The difference, if any, indicates the amount of misregister and is fed back as a correction signal. This is used in the General Electric CR7515-P201.

A high-precision system is shown in Fig. 6. A lens system forms a very bright spot of light which a collecting lens system directs to the tube. A variable aperture controls the light falling on the phototube. A position on the web can be detected to within .001 inch and stray light cannot affect this system. It is used in General Electric type CR7515-P202.

There are three ways to use side register controls. They are shown in Fig. 7. A "payoff" control is used when a web enters a machine (Fig. 7-a), a "mid-line" control in the middle of a process (Fig. 7-b) and a "windup" control at the end of a process (Fig. 7-c).

There are also two *types* of controls: Two-point and proportional. A two-point side register controls the web scanner (3S7515-PS102) discussed earlier. Where the rate of side motion of the web is moderate this system is effective. The edge of the web is normally used as an indication for the phototube, but a printed line will also serve. The control is an on–off system which provides adjustment only when the error exceeds preset limits. There is no control as long as the web is in the neutral zone (Fig. 8).

A proportional control (Fig. 9) has no neutral zone. Instead, it uses the

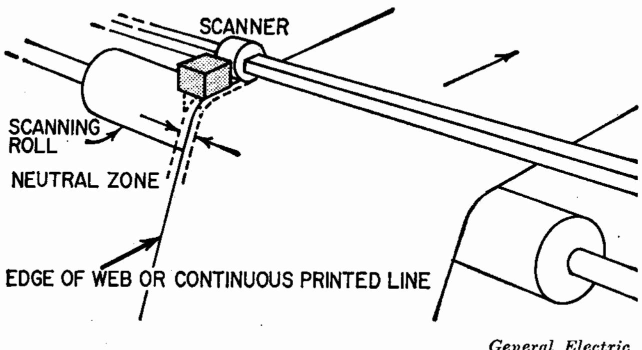


Fig. 8—Two-point side register control system.

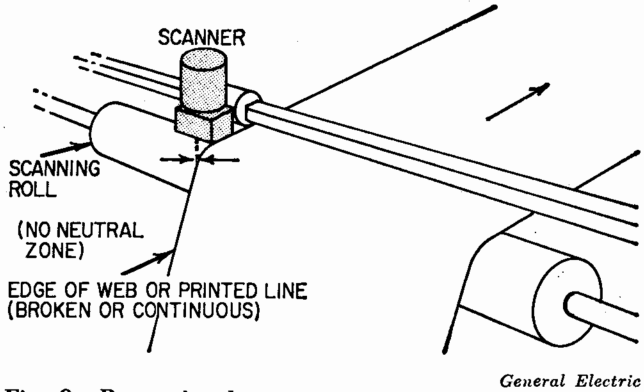


Fig. 9—Proportional side control system.

CR7515-P201 rotary lens scanner. Correction rates go up to 100 inches per minute with an accuracy up to ±.010 inch of web displacement. The control can follow the edge of a web or printed lines, which can be solid, broken, black or colored.

The two-position control has a small differential over which it operates. The differential is defined as the difference between the upper and lower limits. Midway between them is the point to which the control is set. In a proportional control, the sped of the correction is proportional to the amount of error.

Side register control use vacuum-tube circuits which are related to radio. The circuit in Fig. 10 is a simplified drawing of one type of side register control. Because it must respond to slow changes in web motion from side to side, the tubes are direct-coupled. At some position, as in the original adjustment, the web register is correct. Then the light falling on phototube V1 is balanced by R5 and R14 so there is equal output from V5 and V6 and the correction motor does not move.

If the web moves to one side, more light falls on V1 and current increases, creating a greater voltage across R1, which increases the positive voltage on V2's grid. A voltage divider (R3, R4, R5) across the regulated supply voltage provides several reference potentials. R5 is used to vary V2's cathode voltage.

When V2's grid becomes more positive, the tube conducts more, lowering its plate voltage, and, since V2 is direct-coupled to V3, its grid voltage goes down. R2 sets the amount of this change. V3 and V4 form a phase-inversion circuit: as V3's grid goes less positive, its plate current drops. This increases the plate voltage which makes V5's grid more positive, increasing V5's plate current.

At the same time, the lowered cathode current (and resulting cathode voltage) through R6 also affects V4. This tube has a constant positive grid voltage, obtained from the voltage divider, so the lowered cathode voltage increases the plate current. This lowers V4's plate voltage and V6's grid voltage, decreasing V6's plate current.

Now V5 and V6 are out of phase. Each one's plate current becomes a source of driving power for the correction motor through a generator system. There is more current through forward winding F and less through reverse winding R, and the correction motor goes forward to correct for the original error of web motion. We get reverse action when less light hits the phototube (an error in the opposite sense) and the correction motor reverses and goes in the other direction.

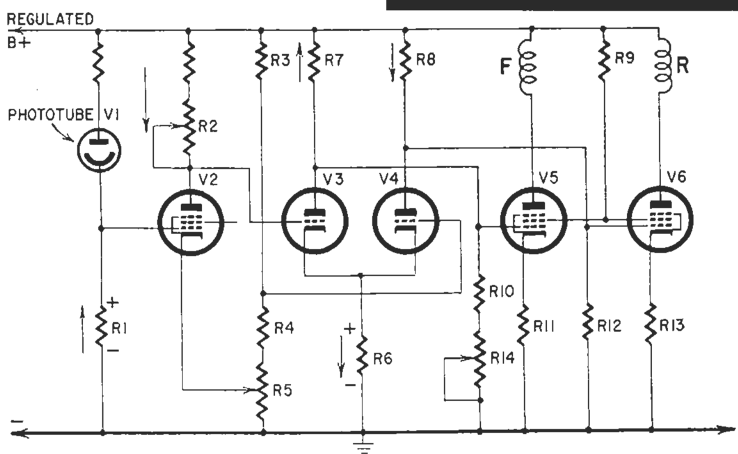


Fig. 10—Circuit of side register control CR7505-S119.

CR7515-S118 side register control

This side register control equipment uses a continuous line or edge of a moving web of material to maintain the lateral position of the web. The photoelectric scanning head detects deviations of the material from its "on-center" position under the scanning head. One of two telephone type relays on the control panel, depending on the direction of lateral deviation, is triggered by the scanner signal. Whenever the material is in register (on center), both relays are de-energized (Fig. 11). If the material moves to one side, more light reaches the phototube and one of the relays (2CR) closes. This relay stays closed until the deviation is corrected. If the material moves the other way, the amount of light decreases and the other relay (1CR) operates. These relays control the reversing motor starter which, in turn, controls the power to the correction motor. The correction motor drives the mechanism to correct the error in lateral register which has been detected.

This two-point side register control is *not* a continuous correction device. It requires a definite lateral variation of the web from the on-center position before any correction is made. Since the web must always be under the scanner, it is a continuous sampling device. The control is set so the referenced edge or line moves through the center of a light beam or spot. With the material in its centered position, a fixed amount of light reaches phototube V1. With the BALANCE control adjusted to match the phototube signal, both relays (1CR, 2CR) are open.

In the balanced condition, both sides of V2 conduct, and both of V4's grids are so biased that the plate currents in both halves of the tube are equal, at some small current which does not energize either relay.

If the phototube receives more light because of a lateral deviation of the material, it passes more current. The current flows through resistor 1R or other sensitivity resistor, making one of V2's grids more postive. This increases V2's plate current. Current also flows through resistor 9R which raises the cathode voltage on the other half of V2. This lowers the grid voltage, and turns off the other half of the tube. The current in one half of V2 increases, while decreasing in the other half by approximately the same amount. Thus, with an increase in light to the phototube, the voltage at V4-a's grid decreases, due to an increased drop, while the voltage at V4-b's grid increases by an equal amount.

When V4-b's grid goes sufficiently positive, that section of V4 conducts enough current to energize relay 2CR. Meanwhile, V4-a's grid has gone negative and that section of V4 does not conduct and relay 1CR remains dropped out.

When the contacts of relay 2CR close, the correction-control devices move the material in a direction to correct the deviation.

As the correct position is approached,

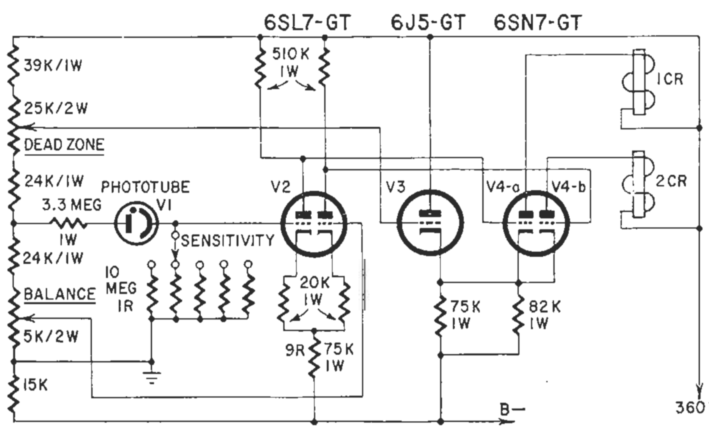


Fig. 11—Partial schematic of G-E type CR7515-S118 side register control.

the light reaching the phototube decreases, V2's grids are again at the same potential and the potentials on V4's grids are matched. V4-b's plate current decreases to its balance value, and relay 2CR drops out.

A decrease in light reaching the phototube, because of a deviation in the opposite direction, runs the control system in reverse. Relay 1CR is energized, the correction is made, the material returns to the in-register position once again, and relay 1CR drops out.

V3 is a cathode follower that keeps V3's and V4's cathodes at several volts positive with respect to V3's grid. With the control in the balanced condition, the voltage on V3's and V4's cathodes determines the bias voltage on V4. Thus the voltage on the cathodes determines the width of the zone (called "dead zone") in which neither relay is energized. By increasing the voltage on V3's grid (increasing the dead zone setting), V3 conducts more, the bias on V4 is increased, and the dead-zone size increases. An increase in the dead-zone size decreases the control's accuracy and the systems tendency to hunt. This adjustment should be set to give the highest accuracy possible without hunting.

So far we have examined side-register photoelectric controls designed to keep the web straight during a continuing industrial process. Next month, we will take a close look at cut off controls that insure cutting a roll of material into exact-size sheets. We will also see what servicing techniques work best for these devices.

TO BE CONTINUED

WHALING BY ELECTROCUTION

The Russian whaling ship *Slava* has been equipped with a unique system to kill whales almost instantaneously. The cable linking the ship to the harpoon is not the ordinary type, but is an electrical conductor. When a whale is harpooned, a powerful electric discharge is sent through the cable to kill the whale painlessly.

The reason given for the adoption of this very humanitarian device is that it does away with the long struggle between harpooning and killing the whale, a struggle that could last hours.

PHOTOELECTRIC REGISTER CONTROLS ...how they work

Part II—Details of cutoff register systems. Troubleshooting and servicing controls

By ALLAN LYTEL

THERE are two basic kinds of register controls—the *side register control* was described last month. This time we will examine the *cutoff register control.* Fig. 1 shows one version of this type of control. The web with the register marks passes through the cutting machine. As it passes under the web scanner, each register mark produces a signal pulse. The cutter, several feet from the phototube, controls the cutting edge and a rotating switch.

When the cutter and register marks are in sync, there is no correction output. This is shown in Fig. 2. The rotating section (selector switch) makes one revolution for each time the cutter does its job. If the cutter and register marks are in sync, the phototube signal arrives when the switch is open and has no effect. However, if the phototube signal is late (when the cutter leads), it is passed through the switch to point C and on to thyratrons that control the drive motor to slow it down. If the phototube signal is early (the cutter lags), the phototube signal passes through the switch to point B and the drive motor is speeded up.

CR7515-W210 cutoff register control

This system is shown in the schematic and Fig. 3. It continuously maintains register between a cutter and the material being cut on any continuously fed cutoff machine. This is done by the control panel which compares electronically the register-mark signal from the scanning head and the cutter-position signal from a selector switch. Any error signal produced by the comparison changes the field current of the pilot generator (which supplies power to the correction motor). Since the generator is driven from a machine at a speed proportional to the material speed, the system compensates automatically for variations in machine speed.

In this system, the correction motor runs in only one direction and errors are corrected by changing its speed from

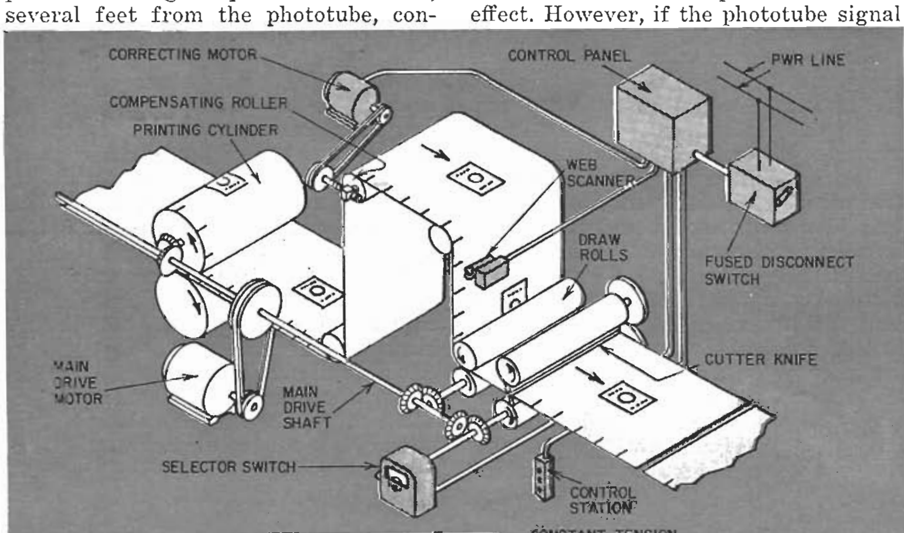


Fig. 1 (above)—Motor-driven compensating roll changes position of web with respect to cutter by changing the length of paper between the printing and cutting processes.

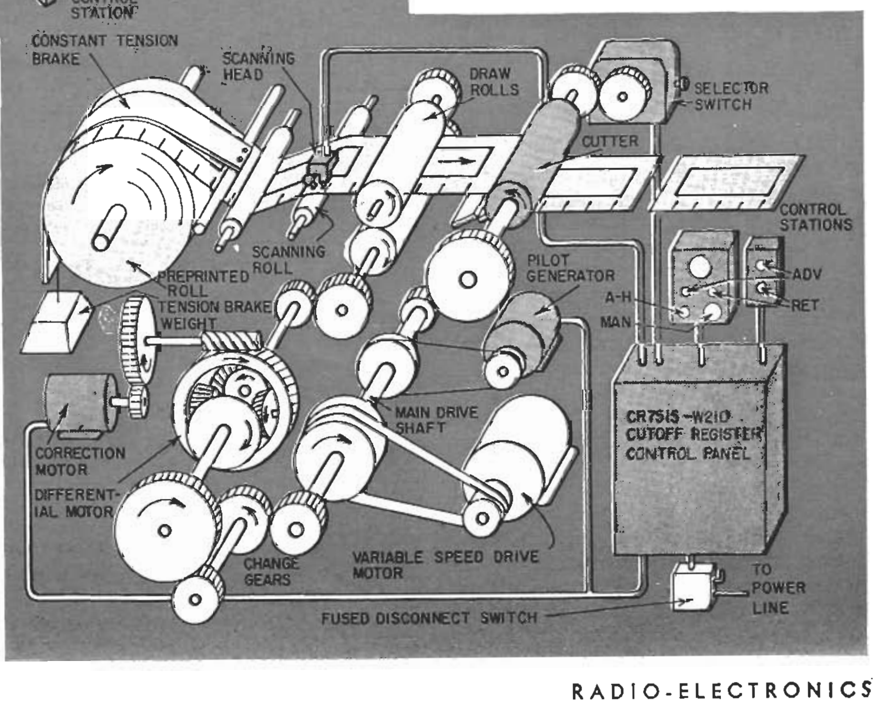
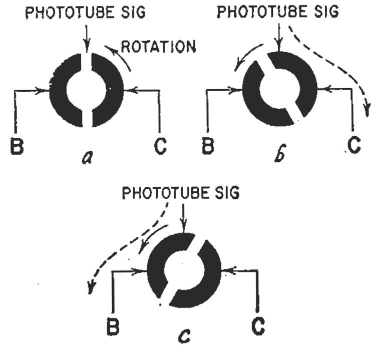


Fig. 3 (right)—Typical application of CR7515-W210 photoelectric cutoff register control system.

Fig. 2 (below)—How selector switch produces error signal.



the preset value or base speed. Actual motor speed is usually lower or higher than its base value so two-way operation is possible without reversing the motor.

Material is normally fed into the machine at a speed slightly higher than required. Then the proper rate of speed is set by selecting the base speed of the motor so it reduces overfeed until the material and the cutter are in register.

The system corrects continuously for any deviation in position between the material and the cutter by either increasing or decreasing motor speed from its base value, thus feeding the material slower or faster to keep it and the cutter synchronized.

The selector switch, which is geared to the cutter, produces a signal which indicates the cutter's position. This switch contains two phototubes, an amplifier tube and a light-source lamp. A disk that rotates inside the selector switch contains six pairs of slots. These slots permit light to strike the phototubes as they pass in front of them. This produces the cutter-position signals (leading and lagging), which are amplified and sent to the control panel. The control will operate for web speeds of 20 to 750 feet per minute and with one to six register marks per cut.

While the control can detect errors as small as .005 inch, the accuracy of the cut depends upon such other factors

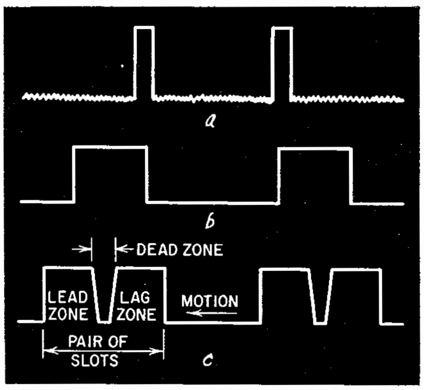


Fig. 4 — Waveforms from: a — web scanner; b — selector switch leading or lagging zones; c—selector switch.

as register-mark spacing, backlash in the gearing, loose couplings, tension control of the web, etc. With an average machine, accuracies of ±1/32 inch are expected, provided the register marks are equally spaced and web tension is reasonably controlled. With an exceptionally good machine and close control over the other variables, accuracies of ±1/64 inch can be obtained.

Register-mark scanner

This unit looks at the register marks printed on the material. The phototube observes the material as it passes a focused spot of light. When a mark passes the light spot, a change of intensity is noted by the phototube, then amplified and sent to the main panel. In this way the position of the material is noted. The scanner operates on either light increase (light mark on dark background) or light decrease (dark mark on light background) simply by setting a toggle switch on the scanner. The output waveform is shown in Fig. 4-a.

Selector switch

The position of the knife or other device working on the material is registered by the selector switch. Two signals are developed: one before the knife cuts (leading zone), and one after the knife cuts (trailing zone). This is done by gearing the unit to the knife so a slotted disk inside the unit revolves with the cutter. On one side of the disk are two phototubes. On the other side is a light source. The slots are arranged so light strikes first one and then the other phototube, thus creating two signals which are amplified and sent to the control panel. An adjustment inside the unit allows the two zones to overlap (light falls on the trailing phototube before leaving the leading phototube) or to have a dead zone (light falls on neither phototube).

Selector waveforms are shown in Fig. 4-b as the signal from *either* the leading or lagging zone. Fig. 4-c shows selector waveforms and indicates the lead and lag zones.

Register mark indicator

Going back to the schematic, V2, a 6E5 indicator, mounted at the top of the panel, indicates incoming register-mark signals. By observing V2, one can see when a register mark is detected by the sudden widening of the shaded area.

Dc bridge

A network of resistors placed between the positive and negative dc buses supplies various voltages necessary for the operation of the panel. These voltages are adjusted by setting slides on the resistors.

Discriminator

In this circuit the positions of the knife and paper are compared. V3 and V4 have two controlling grids; one takes its signal from the register-mark scanner and the other receives its signal from the selector switch. Two tubes are required because there are two selector switch signals, one for the leading zone and one for the trailing zone. The two grids in each tube are normally operated so that no current flows unless a positive signal appears on both grids at once. When the material is in register, both discriminator tubes produce signals or both remain cut off, depending on the adjustment of the dead zone in the selector switch. When the material is out of register, only one tube produces a signal.

Error detection

This stage detects the difference between the precise setting of the cutter knife and the position of the register marks.

Motor control

The normal running speed of the correction motor for a particular machine speed is controlled by the base-speed potentiometer. If the material is in register, correction-motor speed is normal. However, if there is an error, the correction motor runs either faster or slower, depending on the signal coming from the stability network.

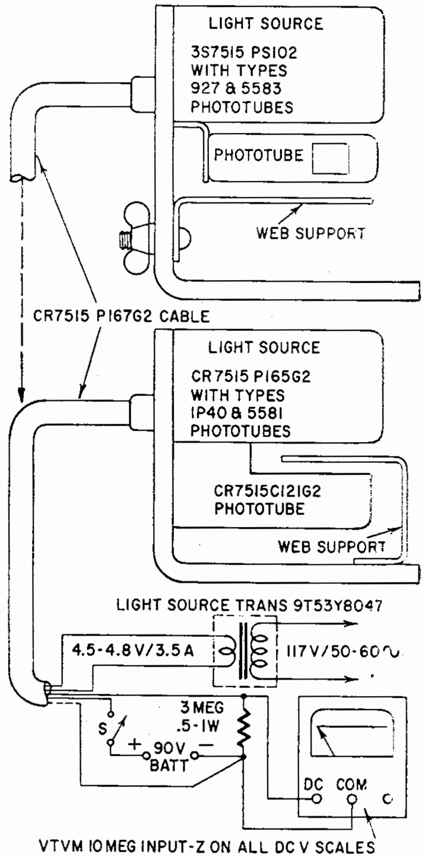


Fig. 5—Register sample tester.

Current through the generator field is regulated. When in register, current is at a value determined by the base speed setting. When an error is detected, field current is varied to correct motor speed. There are advance and retard pushbuttons for changing register while the machine is running.

Servicing techniques

Cutoff register controls

A sample tester, shown in Fig. 5, tests samples of register marks on a web to determine the output signals from the motor control. Two register controls are shown. The samples are set up so that the operating conditions are as close to actual use as possible. A light-source transformer with a 4.5- to 4.8-volt output is required.

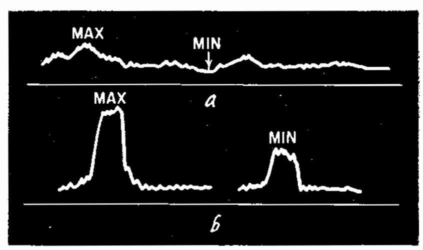
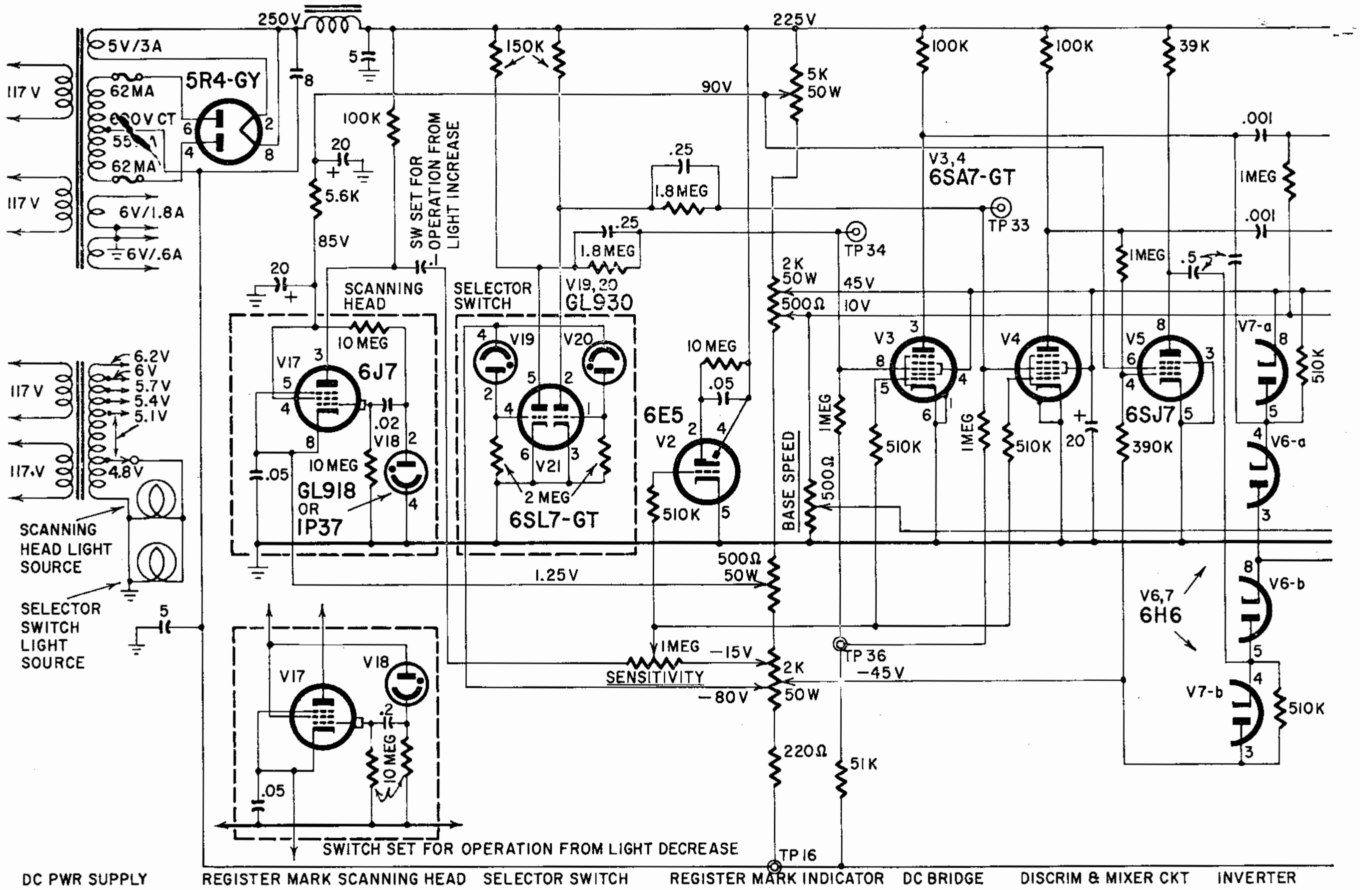


Fig. 6—Characteristics of web (a) and register-mark (b) variations. Register marks must have at least 20 times the amplitude of web variations.



A 3-megohm load, a 90-volt dc source and a vtvm or an oscilloscope are used for testing. When the web is moved so light passes over the register mark, a signal voltage change of at least 0.5 volt is needed to assure normal operation of the controls.

A second important characteristic is shown in Fig. 6. Two conditions are shown, the variations in the web material as in Fig 6-a and the variations in register marks as in Fig. 6-b. In this example a positive signal is shown from the register mark. There are wide variations in some web materials. Both extremes, maximum and minimum, are shown for the web alone and the register marks. For best operation the register-mark minimum should be at least 20 times greater than maximum web variation.

Maintenance

A check of all tubes, except the neon tubes and the phototubes, is desirable whenever the control is serviced. A standard tube checker will do, although it does not guarantee that the tube will work satisfactorily. Some tube difficulties cannot be detected on a standard checker. Keep a full complement of spare tubes on hand at all times and if any tube is questionable, replace it! The tubes and their corresponding sockets should be marked as the tubes must be replaced in the same sockets after checking to insure proper operation. The phototubes have a long life and should not cause trouble unless they are mechanically damaged.

The lenses in the scanning head, its light source and selector switch must be cleaned regularly to maintain reliable operation. The scanning head and the exterior light-source lens must be replaced with the flat side toward the material. The inner light-source lens must be replaced with the flat side toward the lamp.

The rest of the components need no attention unless mechanically damaged. For this reason the unit should be mounted where it is protected against damage from passing vehicles, etc.

Servicing

When trouble crops up, its approximate location and nature can often be determined by the circumstances under which it began. In cases where this approach fails, observational checks should isolate the trouble to a particular section of the control. When the difficulty is isolated, a routine check of circuits and components will indicate the fault.

When troubleshooting, first make sure that the panel is receiving power. This may be checked readily by observing the indicating-eye tube (for green color) and the scanning head and selector switch lamps (for light). If the lamps are lit but the indicating-eye tube is out, check the small panel fuses. If all of these indications are negative, the incoming power lines, including fuses and switches, should be checked. If the lamp in either light source is out but the panel above is getting power, the lamp is burned out and must be replaced.

If the neon tubes flash but the generator field current does not kick, check the detector diode tubes and replace them if necessary. When the diodes are not defective but there is still no generator field current change, check the components in the stabilizing circuit.

Signals from the selector switch may be checked with either a vtvm or an oscilloscope. A 20,000-ohms-per-volt voltmeter will also give a satisfactory check.

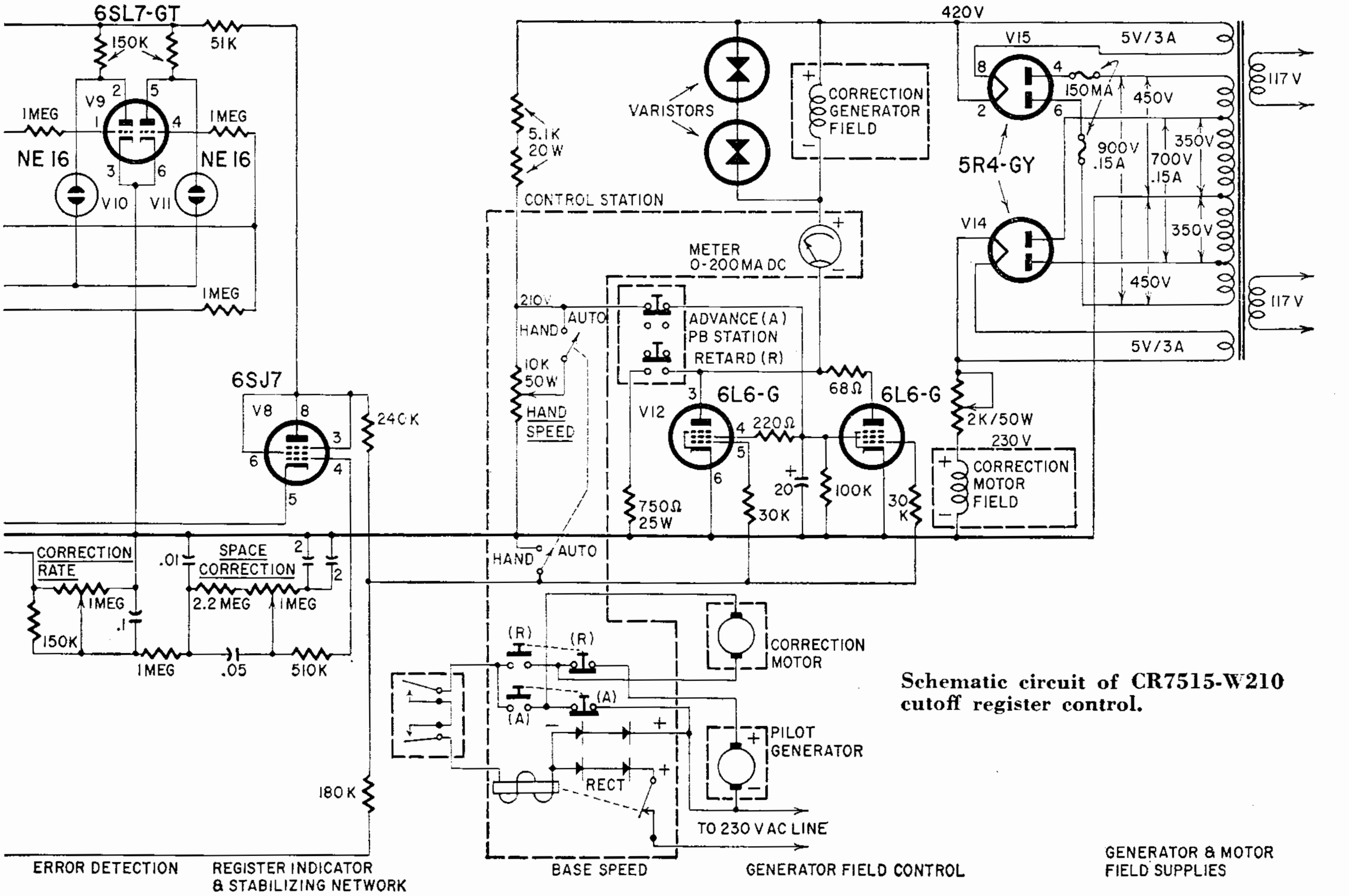
When light falls on phototube V19, a voltmeter connected at TP34 should change from about −30 to +10 volts. This also holds true for V20 and TP33.

It is important that these potentials be as indicated. If this change is not indicated, the amplifier in the selector switch may be bad.

If both tests are positive, place a jumper between the test point and ground and rotate the selector switch by hand. This gives the effect of a continuous register-mark signal. As the disk in the selector switch rotates, first one and then the other neon tube should flash and the generator field-current meter should kick first in one direction and then in the other, but its average value should not change appreciably from its base-speed value.

When the control seems to hold register but does not hold it accurately, check the dead-zone adjustment on the selector switch.

If faulty operation has been traced



Schematic circuit of CR7515-W210 cutoff register control.

to the control, voltages should be checked. A vtvm or a 20,000-ohms-per-volt voltmeter should be used and all measurements made between ground and the point listed, with the common lead being connected to ground. These readings should be made with the machine stopped.

At times it is desirable to run the machine when trouble has been traced to the control. If the machine will not be damaged by being run without material, functions of the control can be observed and checked under these simulated operating conditions.

An oscilloscope simplifies troubleshooting, since the signals from the scanner and selector switch may be followed through the control and the exact spot where these signals are lost can be located.

With an understanding of how the circuit works the trouble may be located readily with an oscilloscope, if it is electrical and not mechanical. With or without an oscilloscope, however, there is no substitute for a thorough understanding of the circuit when troubleshooting.

General

Signals seen on a scope will vary, depending upon the differences in the web material and the register marks. The characteristics of each web material and the register marks must be determined for proper servicing. Fig 7, for example, shows several signal levels from a representative phototube control. In Fig. 7-a, the signal level is set correctly so that only the desired pulse is above the operating level. In Fig. 7-b, the signal level is too low. The control *might* work, but not reliably. The third drawing, Fig. 7-c, illustrates too high a level because the signal and the peak noise pulses are both above minimum. This causes false triggering and improper operation. Only the condition shown in Fig. 7-a is desirable.

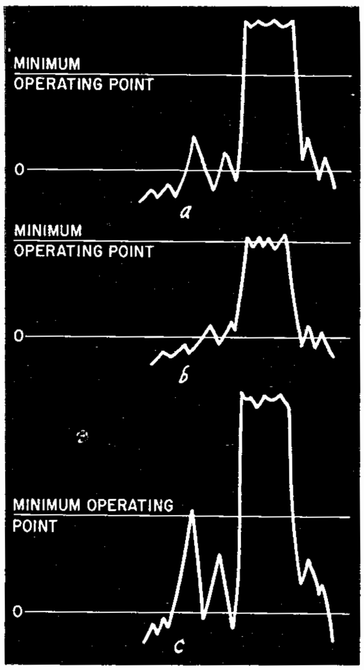
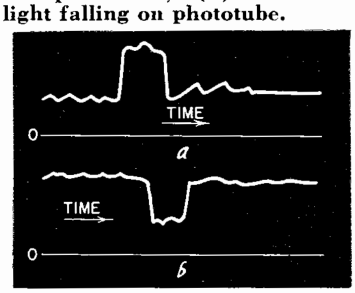


Fig. 7—Effect of signal-level adjustment on register-mark signal: a—correct setting; b—too low; c—too high.

Fig. 8—Pulse formed as register mark passes by (a) increased light falling on phototube; (b) decreased light falling on phototube.



Both negative and positive pulses are possible, depending upon the type of phototube circuit and the number of amplifiers. In Fig. 8 a pulse for light increase is shown in Fig. 8-a and for light decrease in Fig. 8-b.

The following list of servicing checks is suggested as a way to prevent trouble.

1. Check light source for bright, steady light. Lenses must be clean.
2. Check alignment and focus of scanner. Direct interference from other light sources should be kept from the phototube and the register marks.
3. Check signal amplitude and variation.
4. Check line-voltage variations and common grounding. END