PROTECTING AGAINST CARRIER FAILURE

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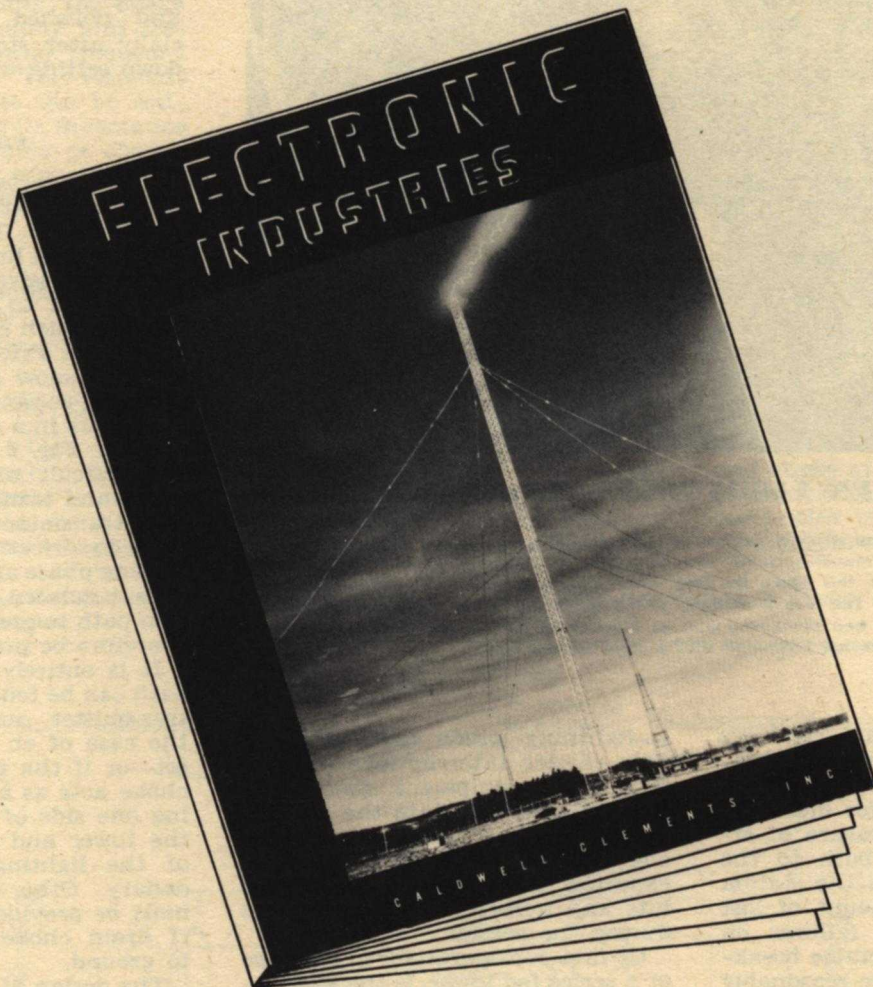
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PROTECTING AGAINST CARRIER FAILURE

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PROTECTING AGAINST

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Practical methods of insuring against interruptions and loss of broadcast time due to lightning and other causes

WHEN LIGHTNING STRIKES

In this photograph of lightning striking the Empire State Building, the central picture was formed by a fixed lens while the surrounding circles were caused by a rotating lens which can be turned at either ½, 1 or 2 rps. In this photo the lens made slightly over 1 revolution. The overlap can be seen at lower right. This was a multiple stroke consisting of an initial long continuing discharge building up slowly and containing a large number of current peaks (bright streaks), and a shorter continuous discharge beginning with a steep current rise

● Most broadcast station engineers take considerable pride in the efficiency of their methods of operation and are on the alert for means of improvement. One measure of effectiveness, apparent both to the listening public and to the station accountant, is the amount of lost program time. Some failures on the air due to unpredictable breakdown of components are reasonably unavoidable—but a large percentage of potential failures can be minimized or eliminated by use of protective circuits and by systematic scheduling of maintenance.

One of the main sources of trouble is lightning which can cause not only carrier interruptions but destruction of equipment. Rising several hundred feet into the air, the modern vertical radiator makes an effective lightning rod and can be expected to receive several direct hits and numerous induced surges during the season.

Of first consideration, in the case of a series fed tower, is the base insulator which must be protected by a spark gap. Protective gaps to ground usually are supplied with the installation, and the only precaution is to see that they are set close enough to protect the insula-
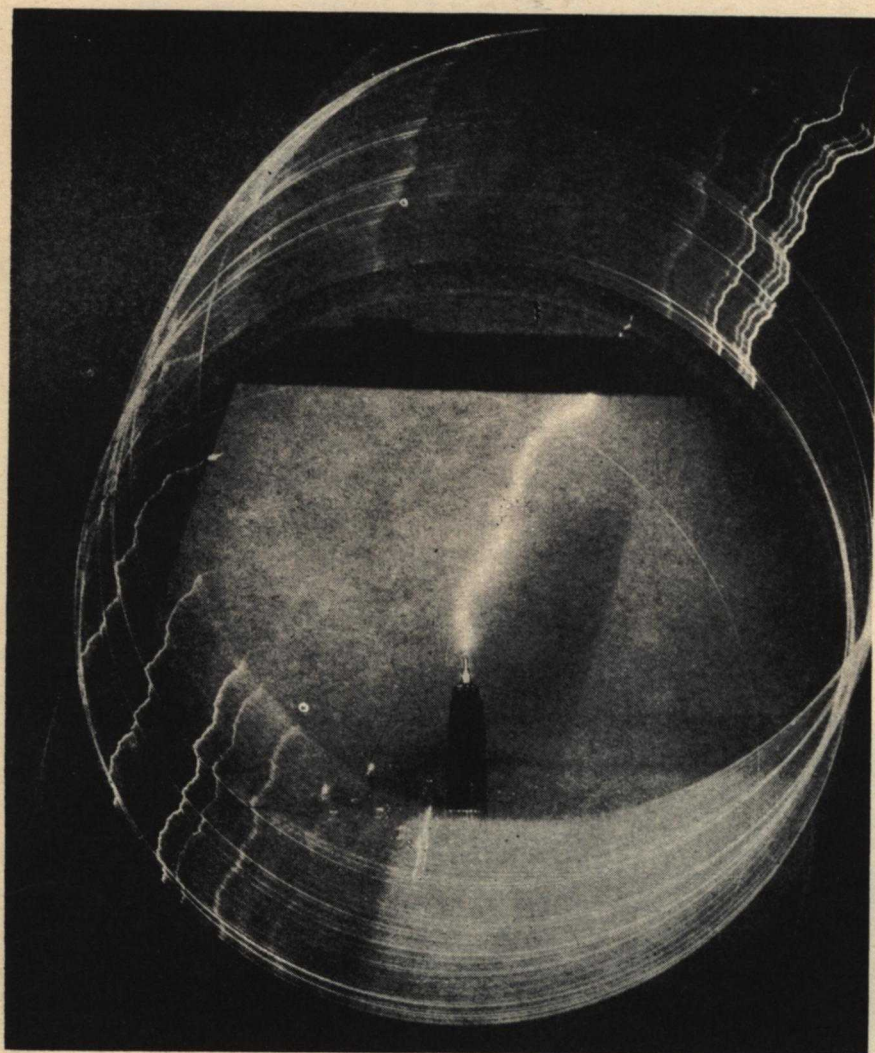
tor. One method of adjusting the gap is to decrease it to the point where it just flashes with heavy modulation and then to double the spacing for normal operation. The gap electrodes should be cleaned and polished occasionally, especially after storms, so the breakdown setting will not change.

Static Drain Chokes

It is important that there be a conduction path from the tower to ground and from an open wire transmission line to ground. Otherwise, successive surges can charge the system to increasingly higher voltage which eventually must flash to ground. Friction caused by wind, sand or snow storms—even smoke from a passing train—can cause flashovers in a completely insulated system. Fig. 2 shows a commonly used circuit which has a floating tower and transmission line. Fig. 3 is a transmission line termination used in directive systems when a leading phase angle is desired. With base insulated towers, no conduction path to ground exists and must therefore be provided.

It is entirely satisfactory if this path can be found back through the transmitter output circuit—as in the case of an inductively coupled set—or if the usual tower lighting choke acts as a drain, by connecting one side of the light circuit to the tower and grounding one side of the lighting transformer secondary. Otherwise, a copper path must be provided by connecting an rf drain choke across the system to ground.

The design of such a choke is not critical as the normal operating voltage is not great, and the choke impedance can be made so high that the normal current through it will be small. The drain choke can be made of approx. No. 20 dcc wire
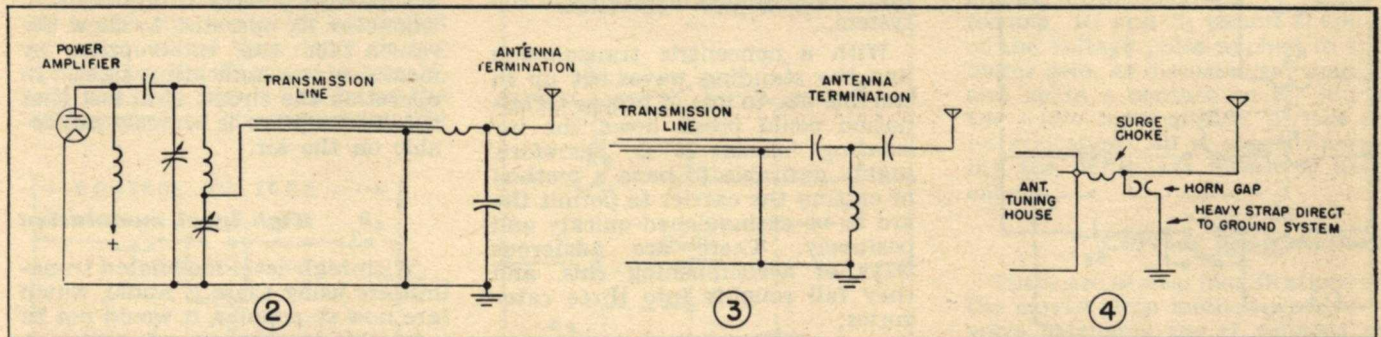
CARRIER FAILURE

Fig. 2—Common termination which permits tower to float, and requires a static drain choke

Fig. 3—Another termination circuit which requires use of static drain

Fig. 4—Arrangement of horn gap and choke coil for protecting against lightning surges

closely wound on a non-hygroscopic form (the first 10 turns should be triple spaced to reduce possibility of breakdown during surges). It is preferable to make the choke rather long and slender to keep the rf voltage per turn low and to keep the distributed capacity down.

For minimum detuning of the circuit which it shunts, the choke should be approximately anti-resonant at the operating frequency of the transmitter. The resonant frequency of a choke can be estimated by calculating its inductance from the usual formula or charts, and its distributed capacity from the approximate empirical equation:

$$C = 1.8 \, D$$

Where C = distributed capacity in micro-microfarads

D = diameter of the coil in inches

The resonant frequency then,

$$F = 10^6 / 2\pi \sqrt{LC}$$

Where F = frequency in kc

L = inductance in microhenries

To protect the line terminating equipment, it is advisable to connect a horn-gap from the antenna feeder to ground at the point where the feeder enters the tuning house.
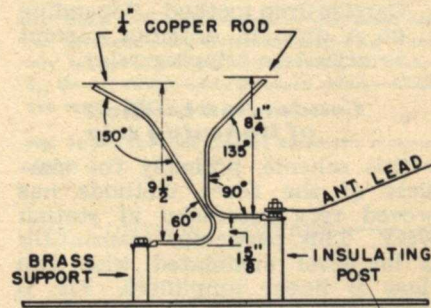

Fig. 5—Horn gap construction that has been successfully used

To increase the effectiveness of the gap it is customary to insert a small choke coil in the feeder on the transmitter side of the gap. This choke can consist of 2 turns wound to 4 in. diameter; No. 4 wire or 3/16 in. tubing makes a rigid self-supporting coil. Fig. 4 shows the connection suggested.

Note that the gap and coil are recommended for grounded tower installations as well as for insulated, as the section of tower below the feeder tap of a grounded tower presents considerable impedance to the lightning surge. Horn-gaps are here specified rather than the commonly used sphere gaps. When a horn-gap flashes, although the transmitter tries to maintain the arc it is automatically cleared due to the inherent design of the horn gap whereas the sphere gap (especially if the balls are mounted in a vertical line as is sometimes done) has much less tendency to clear, and unless other methods are employed to extinguish the arc it may continue until severe damage has been done.

Fig. 5 shows the arrangement of a successful horn-gap based on one described by J. E. Young in Nov. 1937 Broadcast News.

As additional protection to concentric transmission lines, which are especially vulnerable to destruction from lightning surges, it is advisable to use another horn-gap and choke at the tuning house end of the transmission line. With an open wire transmission line it is advisable to use an additional choke

Fig. 6—Circuit using the conduction method of clearing arcs, as applied to low level modulated transmitter

Fig. 7—Conduction method of clearing arc as applied to high level transmitter
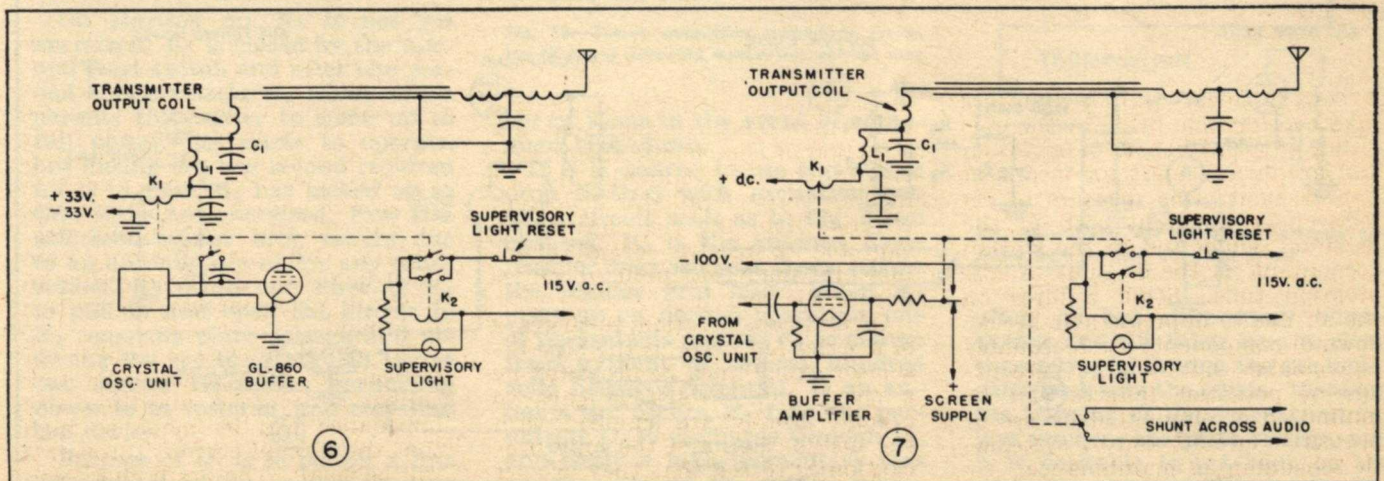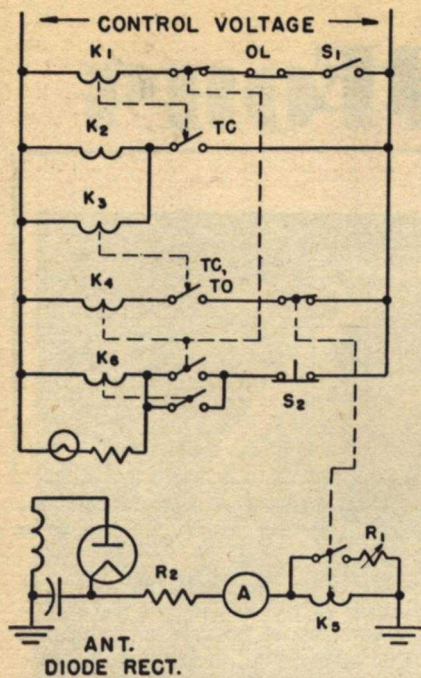
K₁, Main rect. start contactor—K₂, Main rect. run contactor —K₃, TC, to relay, 1 sec. timing —K₄, Trip relay aux.—K₅, Diode circuit trip relay—K₆, Supervisory relay—R₁, Drop-out adjusting resistor—R₂, Meter linearity resistor—S₁, Plate on-off switch—S₂, Supervisory light reset

Fig. 8—Circuit illustrating carrier drop method of clearing arcs

and horn-gap at the point where the transmission line enters the transmitter building. This gives protection from voltages induced into the open wire line.

Carrier tripping circuits

The tendency for a transmitter to maintain an arc once a gap has broken down can be largely counteracted by use of the self-clearing horn-gap. At stations where lightning trouble is infrequent, this protection is often sufficient. But most stations find the horn-gap oc-

casionally is slow in breaking the arc, depending on weather conditions, wind direction, etc. Besides increasing the time off-the-air, this condition can result in momentarily high voltages at other points of the system.

With a concentric transmission line the standing waves set up in the line due to loss of proper termination could break down the insulating beads. It is, therefore, highly desirable to have a method of cutting the carrier to permit the arc to be extinguished quickly and positively. There are numerous ways of accomplishing this, and they fall roughly into three categories;

1 Use of a phototube actuated by the arc flash. This method is not recommended as it protects at only one point of the system.

2 Conduction method—Use of the arc itself as a conducting path for current through a tripping relay.

3 Carrier drop method—depending on a drop in antenna current to actuate a tripping relay.

Conduction method of lightning trip

This scheme, probably the simplest of the three methods has proved very successful at station WGY. This particular transmitter is low-level modulated with two class B linear amplifiers. Fig. 6 shows the circuit used. A low reactance capacitor, C₁, was inserted in the ground side of the coupling coil, and the trip relay, K₁, was connected through a small choke, L₁, to the 33 v. dc filament bus as shown. If an arc to ground occurs anywhere along the transmission line, terminating equipment or antenna, current flows through K₁. When K₁ closes, the rf output of the crystal unit is shorted through a blocking capacitor, dropping the transmitter output to a very low level and allowing the arc to ex-

tinguish—whereupon K₁ opens and the carrier returns to normal. It is of course necessary that all transmitter stages following the trip relay be biased to near cut-off. K₂ is a supervisory relay which seals in whenever K₁ operates, to show the reason for the interruption by means of an indicating light. In operation the circuit is so fast that the interruption is scarcely noticeable on the air.

High level modulation

With high-level modulated transmitters using Class B Audio, which are now so popular, it would not be advisable to short the rf excitation as is done with the low-level modulated transmitter, since high voltage surges in the modulation transformer and its associated reactor might result. One suggested circuit employs a trip relay to apply high negative bias to a control or screen grid through a resistor-capacitor network of about 0.1 second time constant.

Fig. 7 shows the circuit as applied to a high-level transmitter (General Electric Type BT-25A). Note that an additional contact on K₁ shorts the incoming audio line (in the BT-25A a 15 db pad is inserted) to further protect the modulation transformer. With high-level transmitters located where lightning surges are not frequent, it may be simpler to let the trip relay merely open the holding circuit of the main rectifier plate contactor. However, the resulting carrier interruption will be more noticeable.

Note that with this conduction method no drain choke should be connected across the system, but a drain path is provided through the protective apparatus.

Another approach to the problem is indicated by Fig. 8, this method being directly applicable to either high or low level modulated transmitters. It acts to remove plate

Fig. 9—Carrier drop method with excitation cut-off   Fig. 10—Modified carrier drop circuit applied to low level modulated transmitter
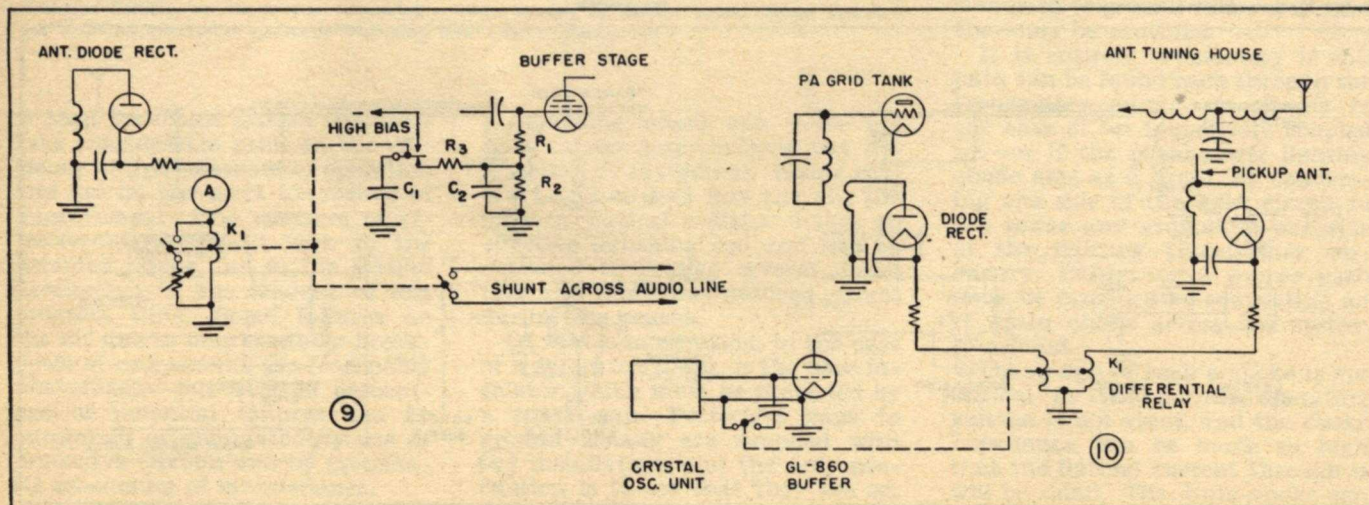
voltage and so causes a more noticeable interruption than does the excitation removal method. K_1 is the usual main rectifier start contactor whose coil is in series with overload relays, interlock circuits, etc. K_2 is the run contactor controlled by a one second time delay closing contact on K_1. Shunted across K_2 is a relay K_3 which can be of the bellows type to give approximately
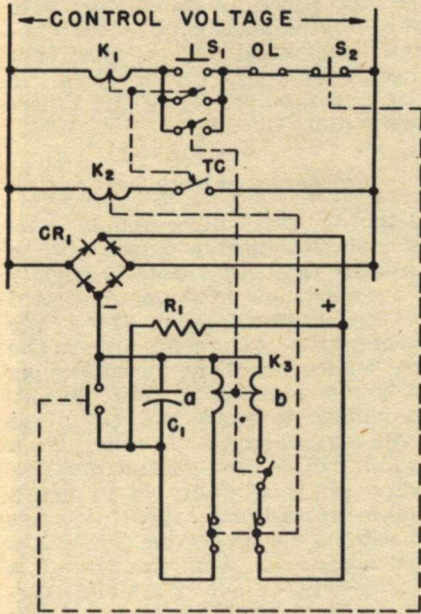
K_1, Main rect. start contactor—K_2, Main rect. run contactor—K_3, Reclosure relay—R_1, Charging resistor 1.5 megohms—S_1, Main rect. on button—S_2, Main rect. off button—CR_1, Copper oxide rect.—OL, Overload relays
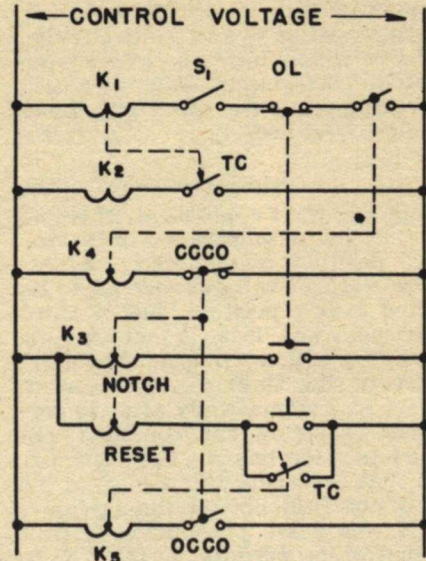
Fig. 11—Automatic reclosure circuit giving one reclosure before lockout

one second time delay in both opening and closing a normally open contact. This contact of K_3 is in series with a normally closed contact of K_5, a relay whose coil is in the dc path of a diode rectifier coupled to the antenna circuit (this diode is usually the remote antenna meter rectifier). K_4 has a normally closed contact in series with the coil of K_1.

On starting up, K_5 is not yet energized; K_1 is closed by the normal start switch and after one second the circuit to K_2 closes which permits the carrier to come up to full power. K_3 starts to operate, but during the one second required for it to close, K_5 has picked up so that K_4 is not energized. Now if a sufficient carrier drop occurs due to an antenna arc or for any other reason, K_5 drops out allowing K_4 to pull in and open the circuit to K_1 removing plate voltage and allowing the arc to extinguish. After one second K_3 opens, permitting power to be restored, and recycling the device.

Purpose of R_1 is to permit a fine adjustment of the carrier level at

which it is desired to have the circuit operate. If desired, K_4 can be tied in with a reclosure circuit so as to recycle only a definite num-

K_1, Main rect. start contactor—K_2, Main rect. run contactor—K_3, Notching relay—K_4, Auxiliary to K_3—K_5, Reset timing relay, 10 secs.—S_1, On-off switch—OL, Overload relays—CCCO, See text—OCCO, See text

Fig. 12—Multi-shot type of automatic reclosure circuit
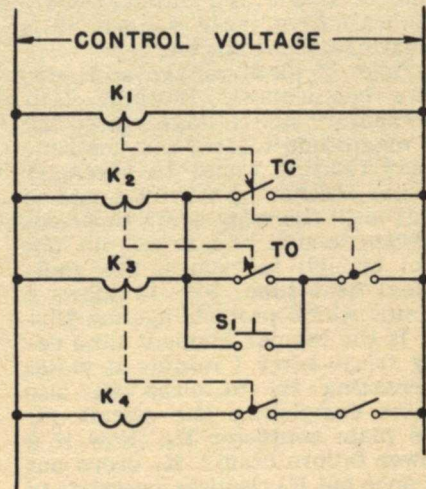
K_1, Fil. time delay relay—K_2, By-pass relay—K_3, Auxiliary relay—K_4, Plate contactor—S_1, Emergency start button

Fig. 13—Circuit permitting immediate restoring of power following momentary voltage drop

ber of times in the event of equipment breakdown.

If it is desired to use the carrier drop method with excitation cut-off, a circuit such as in Fig. 9 can be used. K_1 is the antenna diode rectifier relay. R_1 plus R_2 constitute the regular grid leak. When K_1 picks up on normal operation, one of its contacts permits C_1 to charge from a point of several hundred volts negative potential. If an antenna arc occurs, K_1 falls out permitting C_1 to discharge through R_3, and apply a high momentary bias on the grid of the buffer tube—

this drops the output to near zero and extinguishes the antenna arc. As soon as C_1 has lost sufficient charge, the rf output comes up and K_1 pulls in permitting C_1 to again charge up in readiness for further trouble. R_3 and C_2 permit shaping of the voltage pulse applied to the buffer grid, as discussed previously, and again a contact on K_1 shorts the audio input during periods of no excitation. All rf stages following the buffer are biased to near cut-off.

Carrier drop method

There are several modifications of the carrier drop method which involve balancing the rf voltages at two points. One of these is diagrammed in Fig. 10. K_1 is a relay with two windings excited from diodes coupled as shown. Under normal conditions the two diode currents are equal and the differential relay remains open. However, if anything occurs to upset the linear relation existing between rf voltages at the two points shown, K_1 will operate to short the excitation and break the arc, whereupon K_1 opens and the carrier comes up to normal. If this circuit is applied to a transmitter whose final stage is modulated, one diode could couple to the PA plate tank and the other to the antenna matching equipment.

Another source of outages is from overloads due to 'gas-kicks' in the large tubes and 'arc-backs' in mercury vapor rectifiers. These are
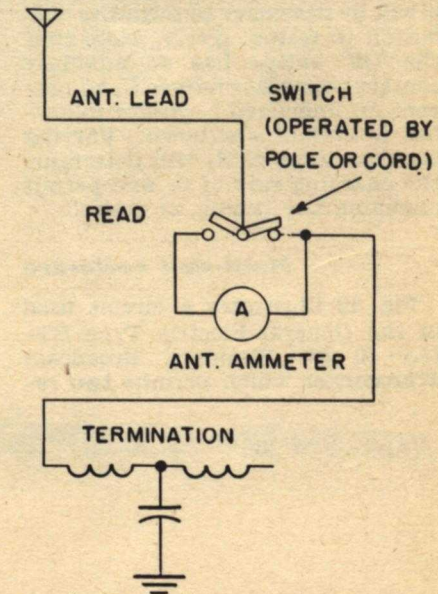
Fig. 14—Circuit for protecting antenna ammeter from burnout when not in use

often of but momentary consequence and the tubes tend to clean themselves by driving the gas molecules back into the anode. However, the tripping of the overcurrent relays removes the plate voltage, and it is desirable to get back on the

air with a minimum of lost time. But the system used must be such that if further overloads continue at a rate endangering the equipment, the power must be held off. Two of the more popular of such 'reclosure circuits' will be described.

Fig. 11 shows a 'one-shot' type circuit which is used on the General Electric G-100A 100 kw international broadcast transmitter. In this circuit, K_1 and K_2 are the main rectifier start and run contactors, while K_3 is the reclosure relay operating on dc from the copper oxide or selenium rectifier CR_1. As shown, with K_2 not energized, C_1 is prevented from charging to appreciable voltage because of the shunt across it presented by the 'a' coil of reclosure relay K_3. After K_1 has been energized for about 10 seconds, C_1 has become charged to a voltage sufficient to close K_3.

Now, if an overload occurs, K_1 and K_2 will fall out permitting the two contacts in the coil circuits of K_3 to close. C_1 discharges into the 'a' coil of K_3 momentarily closing it and permitting the 'b' coil to seal itself in. An auxiliary contact on K_3 shorts across the rectifier 'On' button restoring the transmitter to operation. This permits C_1 to again start charging and after 10 seconds to be ready for another reclosure. However, if another outage should occur in less than 10 seconds, the reclosure relay will not operate and it will be necessary to push the 'On' button to restore power. Note that the 'Off' button has an auxiliary contact which discharges C_1 to prevent an undesired reclosure following a normal shutdown. Varying the resistance of R_1 will determine the charging rate of C_1 and permit changing the timing as desired.

Multi-shot reclosure

Fig. 12 illustrates a circuit used in the General Electric Type BT-25A 50 kw Standard Broadcast Transmitter which permits two reclosures before locking out. K_3, the reclosure relay, is of the notching type with an electrical reset coil. This relay has two separate circuits, one of which has the sequence on notching of "closed—closed—closed—open", while the other has "open—closed—closed—open" for reset timing.

If an overload relay operates, the normally open contacts energize K_3 permitting it to advance to its second position (also closed). A second overload will advance K_3 to its third closed position, but a third overload will lock it out on the fourth position (Open). The purpose of the timing relay K_5 is to reset K_3 automatically after 10 seconds providing the fourth (lockout) position has not been reached, so that overloads over a long period can not 'add up' on the reclosure relay. A reset pushbutton is provided which permits resetting K_3 to position 1 at any time.

Line voltage protection

Most modern transmitters use mercury vapor rectifier tubes. As these require a filament pre-heat time of about one minute before application of plate voltage, it is usual to include a time delay relay to hold off plate voltage until this time has elapsed. However, if a momentary line voltage dip occurs of magnitude to drop out the time delay relay it would be necessary in the absence of other circuits to wait until the relay again times out —even though the tubes did not cool enough to require the additional heat time. Fig. 13 shows a circuit which protects against this. K_1 is the regular filament time delay relay—after 1 minute it closes permitting K_2 to close—K_3 also closes completing the circuit for the plate contactor K_4. Now if a power failure occurs, K_1 drops out at once but K_2 requires 2 seconds to fall out. If the power is restored before K_2 has dropped out, K_3 is picked up at once and plate power can be applied. If more than 2 seconds have elapsed before power is restored, K_2 will also have fallen out and it will be necessary to either wait 1 minute for K_1 to again time out or to push the Emergency Start Button. Caution should be used in use of this button as insufficient timing could injure the rectifier tubes. A good rule is to wait approximately one and one-half times the length of time that the filament power was off (up to 1 minute) before using the Emergency Start Button.

Antenna meter protection

Another piece of equipment vulnerable to lightning damage is the antenna ammeter. This is usually a thermocouple instrument located in the antenna lead above the terminating equipment. Due to the low resistance of the thermocouple it is not feasible to short it out. Removing it from the circuit is more satisfactory. A relay or a switch can be used for this purpose. Although it is desirable to use a make-before-break type, this is not absolutely necessary as the rf arc will carry over until the circuit is closed. Fig. 14 shows a simple circuit which has operated well for this purpose.

If a remote meter is used to give indication of antenna current, it usually will be found that the current transformer and thermocouple often used for this are subject to frequent burn-out. A diode rectifier coupled to antenna circuit will be found more trouble free and cheaper to replace.

That such measures have been successfully utilized is attested by the fact that some stations, even of 50 kw power, lose as little as 30 seconds during a broadcast year of 7000 hours. To achieve such a record, it is necessary to give careful attention to details, and it is hoped that the above brief description may prove helpful to station engineers.

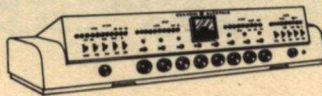# "THIRTEEN MILES OF GROUND WIRE"

625-Foot Vertical Radiator Antenna. General side view showing insulated guy wires extending in four directions, and rows of earth on ground which show location of trenches radiating from tower base, in which are imbedded thirteen miles of ground wire. Old antenna supporting towers can be seen in background. Part of G-E Radio Broadcasting Station WGY at Schenectady, N. Y.

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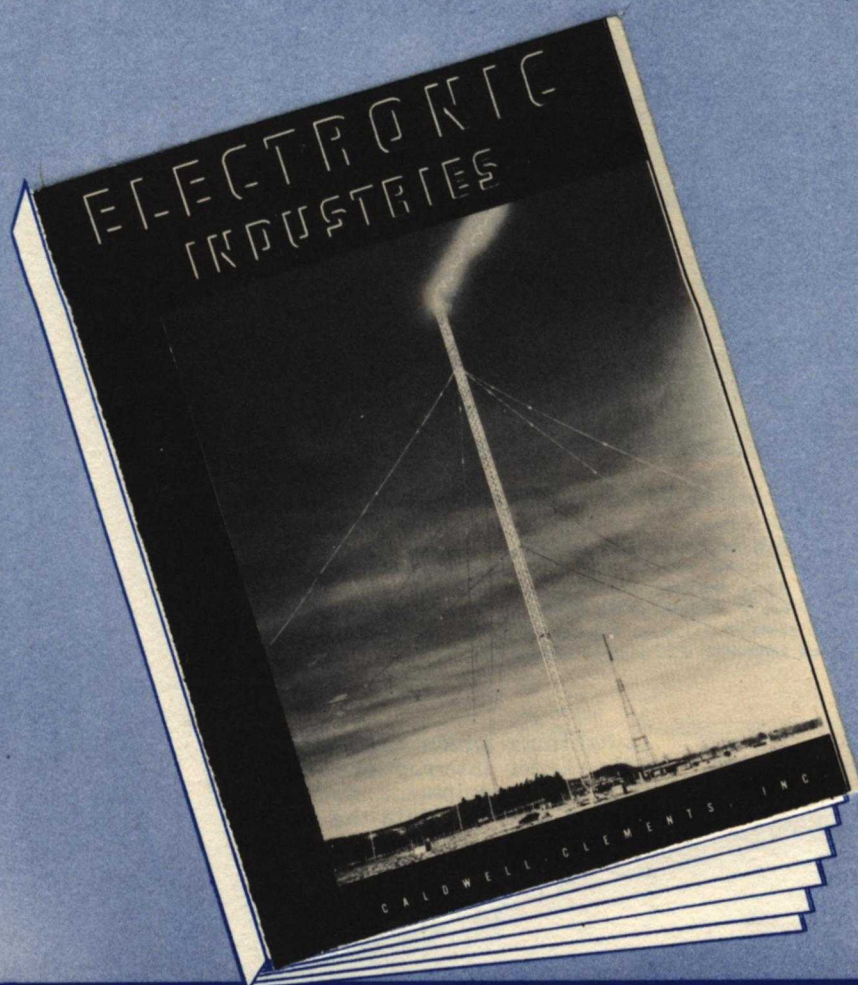
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