# Recent Track Circuit Developments

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**The following is an abstract of a paper presented by Mr. Staples at the Cincinnati Sectional Meeting of the Signal Section, AAR. Mr. Staples is Section Engineer, System Analysis, Union Switch & Signal—Division of Westinghouse Air Brake Company.**

Phase selective ac coded track circuits with dc track relays provide improved defective insulated joint protection and a high degree of shunting sensitivity, broken rail and foreign current detection.

In the coded detector arrangement, where it is not necessary to distinguish between different code frequencies, the track can be a retained neutral relay. It can detect code without requiring a code following relay. Twenty-one of these track circuits have been in service for 17 months in two interlockings at New Haven.

The new phase selective ac coded track circuits were developed to replace centrifugal frequency relay track circuits in ac electrified territory. Use of dc relays reduces the maintenance required by the ac relay. They require considerably less equipment than the single element ac coded track circuits with lockout now extensively used in ac electrified territory.

The new circuits have a flexibility which permits their use in most of the coded wayside and cab signaling systems now in use. Installations of ac single element coded track circuits now in service may be readily converted to phase selective two element circuits with the substitution of new track units and modification of the code following track relays; this feature is of particular value where it is difficult to maintain insulated joints, even in non-electrified territory.

The design of the unit elements and the adjustment of the limiting impedance, a resistor or reactor, is such that during the **on** period of code, the track and local secondaries buck, so that output voltage $E_1$ ex-

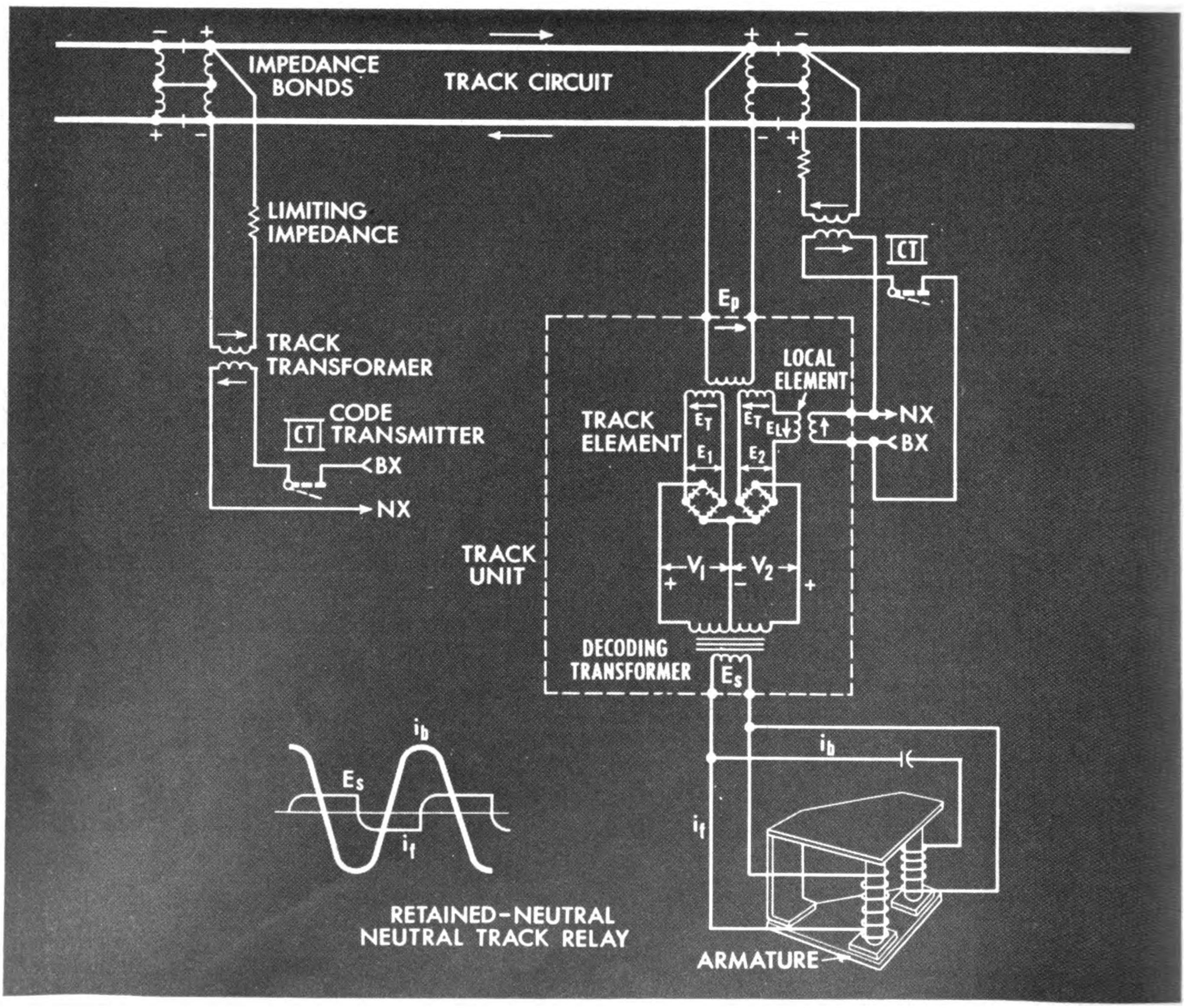



**Fig. 1—The circuit diagram for the phase selective ac coded track circuit. Voltages $V_1$ and $V_2$ may be utilized in other arrangements.**

ceeds output voltage $E_2$. (See Fig. 1.) However, during the off period, the track element transformer voltage, $E_t$, is negligible, so that output voltage $E_2$ exceeds output voltage $E_1$. Thus, when the feed end of the track circuit is coded, the differential in the output voltage alternates at the code rate.

However, if an insulated joint becomes defective with staggered polarities, $E_p$ and $E_t$ will be reversed, and the track and local element secondaries add, so that output voltage $E_2$ exceeds output voltage $E_1$. Thus, coding from the adjacent track circuit over defective insulated joints does not change the direction of the differential between the outputs.

Summarizing, during the off period of coding, or when an insulated joint is defective, $E_1$ is less than $E_2$. During the on period, $E_1$ will be greater than $E_2$.

The two ac output voltages are converted to dc output voltages $V_1$ and $V_2$ by full wave rectifiers. Thus, under normal unoccupied conditions, voltage $V_1$ will be alternately greater than or less than voltage $V_2$, alternating at the code frequency. In case of a shunt or feedover from the adjacent circuit, voltage $V_2$ always exceeds voltage $V_1$. In case any part of the unit shorts or opens, alternation of the voltage ceases. Even a high degree of ac frequency selectivity is obtained with this arrangement, because the bucking required to alternate the output voltage difference is effective only if the frequencies applied to the local and track elements are within a few cycles.

The dc output voltages $V_1$ and $V_2$ may be fed directly into a double-coil magnetic stick code following relay, such as the Style CDP. This arrangement can be used for different code frequencies, using standard decoding. It is possible to use steady energy for block indication or traffic locking, so that any of the basic coded track circuit control systems may be used. The code following relay follows the code transmitter only when the entire circuit is intact. Operable track circuit lengths are the same as for single element coded ac track circuits.

Where only track circuit detection is required and where the track circuits are fairly short, as in interlockings, the code following relay can be eliminated by feeding the dc output voltages $V_1$ and $V_2$ into a decoding transformer. This transformer has a core of rectangular hysteresis loop material, so that alternating output voltage $E_s$ is obtained only when the input winding is being pole changed, which occurs only when the track circuit is properly coded. (See box for more details on this transformer.)

Output voltage $E_s$, under normal conditions, is nearly a square wave voltage alternating at the code frequency. This is fed directly into the front coil and through a capacitor into the back coil of a retained-neutral relay, such as the Style DN-26 or PN-67R. This relay has three cores, on two of which are placed coils. The current in the front coil $i_f$ and the flux through the front core follow the voltage $E_s$, but the current through the back coil $i_b$ and the flux through the back core lead the voltage $E_s$ because of the series capacitor, so that the flux reverses in one core while the flux in the other core is a maximum. The third core offers a return path for the unbalanced flux. In effect, the field rotates through the three cores, holding the armature in its closed position.

This combination is designed to operate on one code frequency, al-

## More about the Decoding Transformer

**At the request of the editors, Mr. Staples has expanded his discussion of the decoding transformer.**

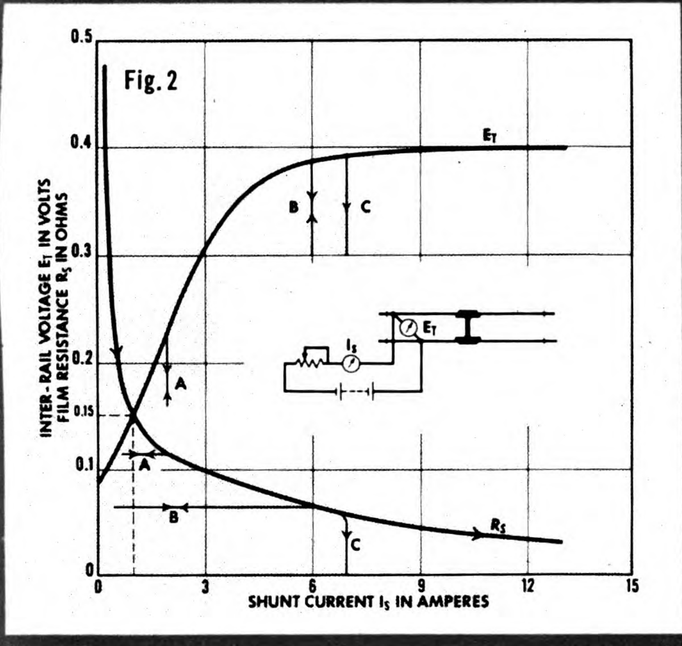
The rectangular hysteresis loop material performs the same function as the magnetic stick code following relay in the other arrangement, i.e., the winding energy has to be pole changed at the code frequency in order to actuate the decoding equipment. Thus, any difficulty in the circuit, or improper phase, renders the circuit inoperative.

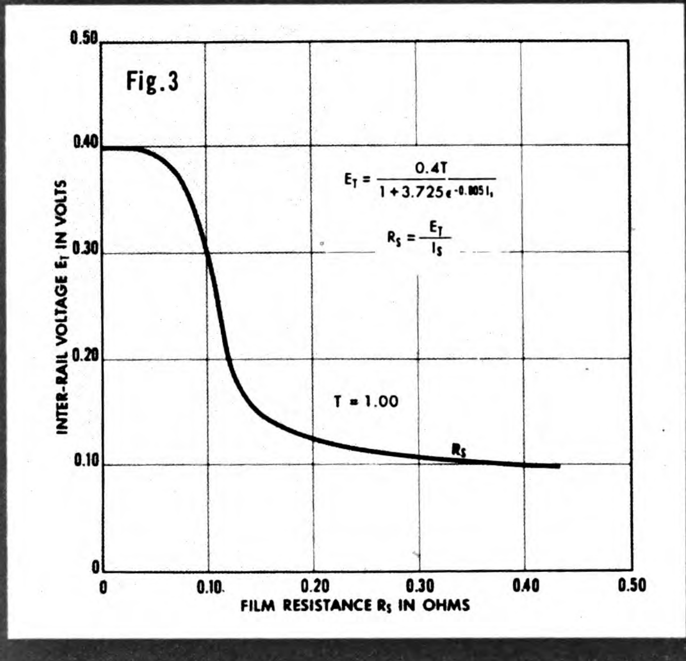
If ordinary transformer steel were used, one of the input windings could be coded with the other input winding open; and an output voltage would be obtained, because the flux would drop to a relatively low value during the "off" period of energization. While the output would be less than half of the nominal output when pole changed, it might be sufficient in certain cases to hold up the decoding relay. However, with the rectangular hysteresis material, the flux remains at the same level when energy is cut off, so that if it is not pole changed, the steel saturates in a short period and no further output is obtained until a reverse magnetizing force is applied.

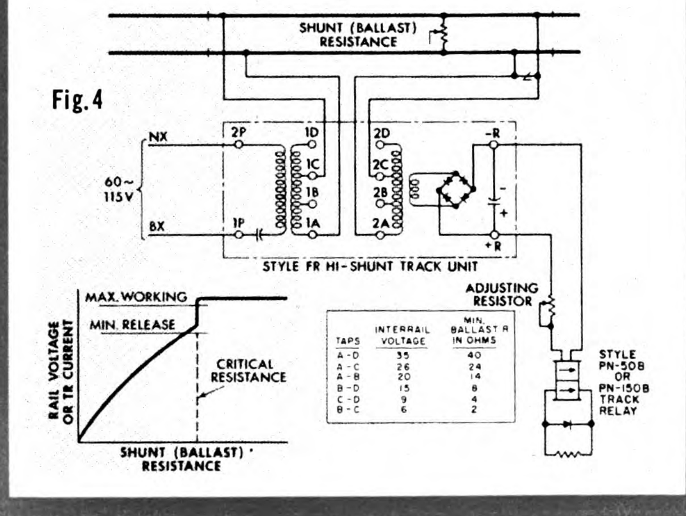
Obtaining a square wave alternating voltage output is primarily a matter of design of the transformer. The output voltage is the induced voltage in the secondary, less the IR drop. The primary induced voltage is essentially the impressed voltage, less the primary IR drop. The primary current is made up essentially of the load current and the magnetizing current; but, of course, the magnetizing current is related to the induced voltage.

As long as the transformer does not saturate, the magnetizing current is relatively small and the IR drops are also relatively small, so that the output voltage is approximately a square wave, when the input voltage is a square wave. The higher the permeability, the lower will be the magnetizing current and the closer the output will be to a square wave. It is necessary to use a big enough core structure that it will not saturate during half of the code cycle.

Since the induced voltage is a function of the rate of change of flux, the total flux change in the structure is a function of time, so that the bigger the structure, the longer it will take to saturate. A core size was selected which would not change from saturation in one direction to saturation in the opposite direction, during a half code cycle. At the minimum energization of the equipment, this establishes the minimum rectified dc energization which has to be applied to the primary windings; at this point the load current is sufficient to energize the decoding relay. As the energy is increased beyond this point, as under high-ballast conditions, the impressed and induced voltage will be greater and the transformer may saturate in less than a half cycle. This could result in a peaked output voltage, if carried to an extreme. However, the output energy during the half cycle remains substantially the same, because the voltage and current output are increased but last for a shorter time. Since the relay itself is an integrating device, it operates with approximately the same margins regardless of the energization of the decoding transformer above the minimum working conditions.




| TAPS | INTERRAIL VOLTAGE | MIN. BALLAST R IN OHMS |
|---|---|---|
| A-D | 35 | 40 |
| A-C | 26 | 24 |
| A-B | 20 | 14 |
| B-D | 15 | 8 |
| C-D | 9 | 4 |
| B-C | 6 | 2 |

though it can reset on other code frequencies where cab signaling is involved. It has very high shunting sensitivity, having an unusually high release to pick-up ratio, quick release and slow pick-up. Generally a slow pick-up repeater relay will be required to take care of possible bobbing during the first two cycles of code until the phasing of the current in the two coils gets in step. This repeater relay also greatly improves defective insulated joint detection and momentary loss of shunt protection.

The track unit, including the decoding transformer, is housed in a Style W-20 transformer case. A smaller unit can be used with the code-following relay arrangement.

### Hi-Shunt Track Circuits

The Hi-Shunt track circuit has been developed to overcome the problems presented by film coated short track circuits in automatic classification yards. Over a period of years we have made many observations on rail and wheel films. The curves in Fig. 2 are an average of a number of tests, with one or two axles standing in the circuit, the car spotted at a high resistance point. As the current is increased, the film resistance drops. In some cases the curve is reversible: decreasing current increases resistance. More commonly, when the current is reduced, the film resistance stays the same, as at A or B, but if the current is further increased, the resistance is reduced still more. In some cases, as at C, the film suddenly punctures, and resistance becomes negligible. The corresponding interrail voltage is shown on this curve.

The curve in Fig. 3 shows the relationship between the interrail voltage and the film resistance, and the characteristic formula. The values are for a film of unit thickness, such as may be encountered on main lines with dirty wheels. Since the film resistance is a function of the current through it, thicker films increase both the interrail voltage required to pass a given current, and the film resistance, proportionally to the thickness. Thus, the shape of the curve does not change with a change in film thickness.

The Style FR Hi-Shunt track circuit, Fig. 4, makes use of a series ferro-resonant circuit, consisting of a capacitor, non-linear reactor, and resistive load. In this case, the track circuit load is connected across a secondary winding of the non-linear reactor. As the shunt resistance increases, the interrail voltage increases up to a critical value, at which point the reactor suddenly passes into saturation, and the interrail voltage suddenly rises. Since the reactor is saturated, the interrail voltage will not rise appreciably at higher ballast resistances. Consequently, the track relay current and pick-up and shunt times remain relatively constant.

In applying the Style FR Hi-Shunt track unit to a track circuit, taps are selected which provide for a critical resistance slightly below the minimum ballast resistance. We have used taps A-C at West Conway without any low ballast trouble. The same taps are used on the track relay rectifier transformer. In case lower ballast resistance is encountered, both sets of taps are changed in accordance with the table.

Now let us see how you can improve your shunting performance on conventional dc track circuits where you may be having trouble due to rail or wheel film.

In Fig. 2 you saw a set of curves which showed the relationship between axle current, interrail voltage and film resistance. These curves represented average values for dirty spots on wheels on main line track, taken from many field tests. For instance, with 1-amp axle current, the interrail voltage averaged 0.15 volt, indicating a film resistance of 0.15 ohm. Higher interrail voltages lowered the film resistance; lower interrail voltages raised the film resistance. These average values we called unit thickness.

Obviously, the normal film must be much less, or 0.06 ohm shunting sensitivity would have no meaning. However, from shunting performance we know that sometimes the film is much greater. It is desirable to make the interrail voltage penetrate the film encountered, so far as possible, covering up the momentary losses of shunt with a slow pick-up repeater relay.

The curves in Fig. 5 show the effect of the battery limiting resistance adjustment on the maximum rail or wheel film thickness which can be penetrated sufficiently to shunt the track relay, the scale being in previously defined units of thickness.

These curves are for a typical track circuit using a single lead storage cell with an 0.5-ohm Style DN-22BH relay, with a series resistor $R_t$ adjusted to provide working current in the track relay at minimum total ballast resistance $R_b$. As battery limiting resistance $R_x$ is reduced, resistance $R_t$ must be increased. The film thickness which can be penetrated is determined at infinite ballast; it will be greater at lower ballast resistance.

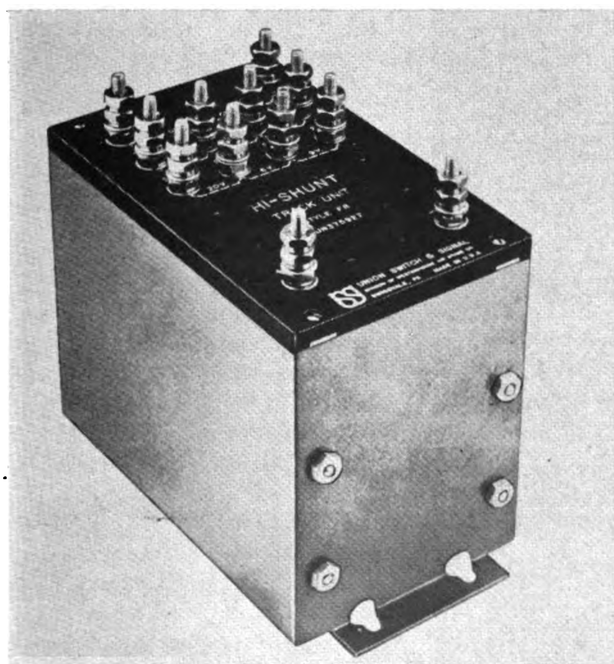
You will note that if the adjustment is made entirely at the battery end so that $R_t$ is zero, the penetrable film is only a little over unit thickness. Decreasing $R_x$ and increasing $R_t$ improves the film shunting characteristic considerably. These curves also show that the higher the minimum ballast, the better the shunting.

If the minimum total ballast resistance is 0.7 ohm or less, it is best to make the battery limiting resistance as low as possible. This would correspond to a track circuit about 4,000 ft in length with a minimum ballast resistance of about 3 ohms per thousand feet.

For shorter or higher ballast resistance track circuits, there is an optimum resistance setting, as shown by the dotted line. The 5-ohm ballast figure might represent a typical "OS" track circuit, with 600 ft of track at 3 ohms per thousand feet. For this circuit, the best value for $R_x$ would be about 1.25 ohms, and then $R_t$ would be about 3.5 ohms.

There are other advantages in using an adjustable resistor in series with the relay. It is easier to set the relay current properly, and the shunting is made faster. The quicker shunting also improves shunting performance and reduces joint-hopping problems, which are a factor with single unit self-propelled cars.

Higher resistance track relays will shunt with a somewhat thicker film, but the relative series resistance is lower, so that shunting time is longer, and shunting performance is not necessarily improved. Conventional relays, such as the Style DN-11, will shunt through only two-thirds the film that the Style DN-22BH will shunt.




Union Switch and Signal's style FR Hi-Shunt track unit.

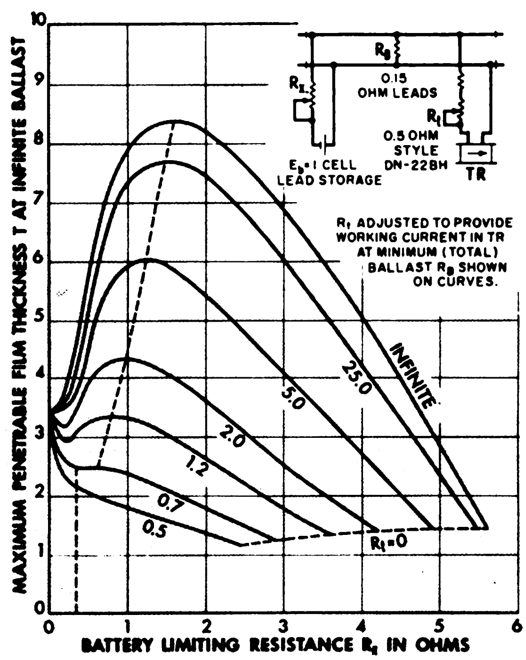



Fig. 5—Dotted line indicates optimum battery limiting resistance, $R_x$.

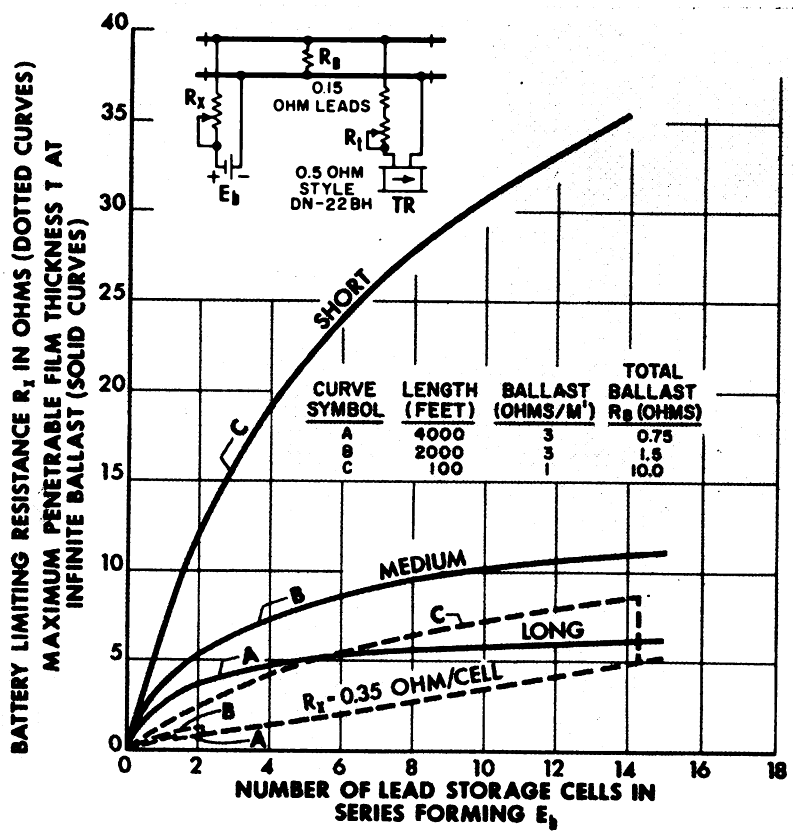



Fig. 6—These curves show the effect of increasing the cells in series in the track battery.

Cicero Yard on the CB&Q. Shorter track circuits in advance of switches are now feasible.

Film shunting can be improved by raising the battery voltage. For instance, if you use two lead cells in series, double $R_x$ and double the minimum ballast $R_b$, the penetrable film thickness is also doubled. Of course, in a specific track circuit you cannot readily change the minimum ballast, so the film thickness is not quite doubled.

The actual effect of increasing the number of cells in series in the track battery is shown on the curves in Fig. 6. They represent three typical track circuits, a long circuit A, a medium length circuit B, and a short track circuit C.

The break points in the dotted curves indicate where it becomes desirable to reduce the battery limiting resistance to a minimum, instead of using a calculated value. These points occur where the number of cells is about 1 1/2 times the minimum total ballast resistance.

In general, with the 0.5-ohm Style DN-22BH track relay, you can set $R_x$ at about 1 ohm per cell above the break point. $R_t$ should then be set to provide working current at minimum ballast. $R_t$ will be about 3 ohms per cell. In long track circuits there is not much advantage in using more than two or three cells in series, but in shorter track circuits a much higher voltages can be used.

Alternating current or ac-dc track circuits have better shunting performance at the same corresponding voltages, because the film current-resistance characteristic tends to knock off the peak of the ac wave.

In general, we have found that raising the battery voltage to about three or four volts, with about four amperes short circuit current, has resulted in satisfactory shunting on branch lines, when a slow pick-up track repeater relay is used to cover momentary losses of shunt. Of course, excessive sanding creates an unshuntable condition, and should be prohibited.

Where rail or wheel film has created a shunting problem on main or branch lines, we recommend the use of two lead or three nickel storage cells in series or equivalent, a 0.5-ohm Style DN-22BH relay with series resistor, and a slow pick-up Style DN-18 track repeater relay or plug-in equivalents. For short detector track circuits, as in automatic classification yards, we recommend the Style FR Hi-Shunt track circuit.