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SERVICE MANUAL 6078

AUDIO FREQUENCY OVERLAY VS. DC TRACK CIRCUIT

APPLICATION INFORMATION

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TABLE OF CONTENTS

SECTION I

AUDIO FREQUENCY OVERLAY VS. DC TRACK CIRCUIT APPLICATION INFORMATION

1.1 PURPOSE OF THIS REPORT

It is suspected that some misunderstanding exists about the principles of Audio Frequency Overlay (AFO). Because of the long existance and acquired familiarity with the conventional mainline D.C. Track Circuit it is believed that some maintenance personnel are attempting to adjust AFO track circuits in the same manner as the conventional d.c. track circuits. Doing this could create any number of serious side effects.

It is the purpose of this report to clear up any misconceptions by explaining how each circuit operates, the influencing factors and why proper adjustment is required.

1.2 SCOPE

This report will first cover the function and role of D.C. Track Circuits, operational considerations, and their adjustment. Specifics which will be discussed include Theory of Operation, Changes in ballast resistance, shunting sensitivity and broken rail detection.

Second, a description of operation of Audio Frequency Overlay (AFO) its purpose and function, theory of operation, circuit parameters, adjustment and multiple installations will be presented.

SECTION II

MAINLINE DC TRACK CIRCUITS

2.1 INTRODUCTION

The purpose of the D.C. Track Circuit, invented August 20, 1872, by Dr. William Robinson, is to Provide Positive train detection in order to control mainline railroad signals. In addition to the positive train detection, 0.06 ohm shunting sensitivity, d.c. track circuits must provide broken rail detection, or detect a break in bonding wires around an insulated joint.

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2.2 D.C. TRACK CIRCUIT PARAMETERS (Reference Figure 2-1)

The physical and electrical lengths of the d.c. track circuits are established by the placement of the two pair of insulated joints on the rail. The length of this track circuit is sharply defined to that portion of track between the insulated joints.

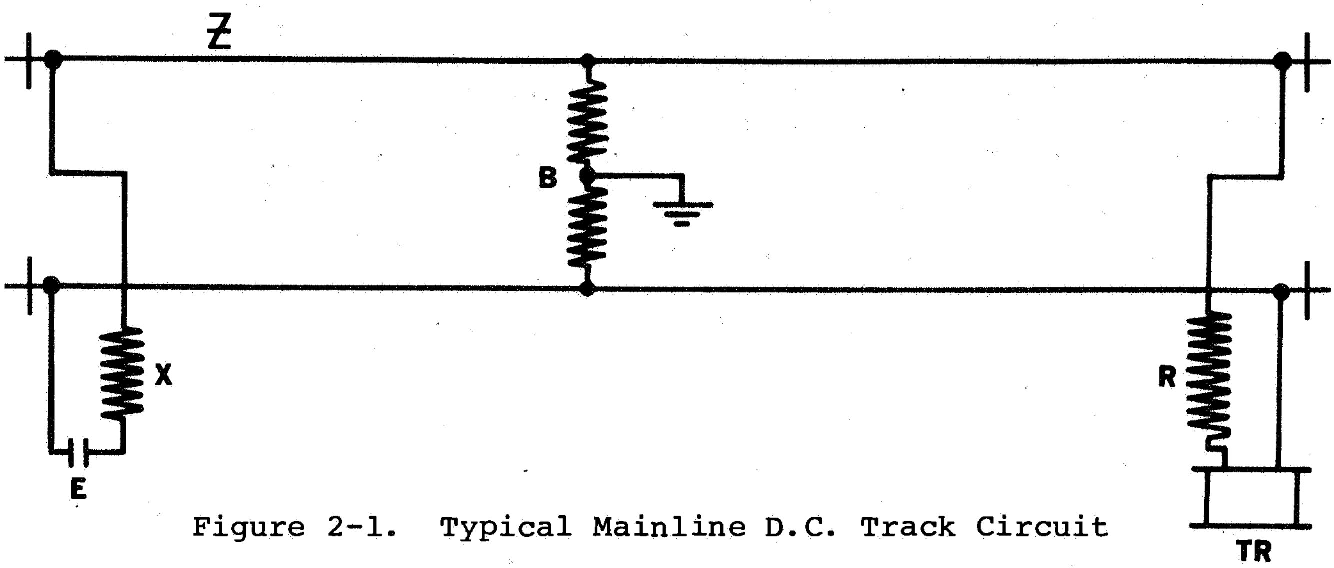


Figure 2-1. Typical Mainline D.C. Track Circuit

Maximum D.C. track circuit length can only be safely arrived at after considering the factors which are involved:

1. Source Voltage "E"
2. Limiting Resistances "X" and "R"
3. Track Relay's ("TR") Level Detection
4. Track Relay's ("TR") Resistance
5. Ballast Resistance "B"
6. Rail Resistance "Z"

2.2.1 Source Voltage

The first concern is with battery voltage variation; the minimum voltage at which the circuit must operate properly at minimum ballast conditions; and the maximum voltage at which the track relay must release with an 0.06 ohm shunt or broken rail within the circuit. The smaller the voltage variation, the longer the track circuit that can be safely worked for a given minimum ballast. Or the smaller the voltage variation, the lower the minimum ballast that can be safely worked for a given track circuit length.

For years the railroads have made efforts to improve the voltage variation associated with track circuit work by good battery maintenance programs. The following tabulation shows two sets of battery voltage variations, one for track circuit applications, identified as B, and one for heating and critical timing problems, identified as A.

TYPE OF BATTERY	B MIN. - MAX.	A MIN. - MAX.
Lead Storage	2.0 - 2.3 Volts	1.75 - 2.7 Volts
Nickel Storage	1.2 - 1.6 Volts	1.1 - 1.75 Volts

Experience has shown that the railroads have been able to maintain these closer battery limits with reasonable maintenance programs. The rewards for these good maintenance programs are clearly shown on Figures 2-2 and 2-3.

Figure 2-2 shows the maximum D.C. track circuit length possible for a given minimum ballast, or vice-versa for the high ratio of release current to working current for the DN-22BH track relay. Two curves are shown, one for terminal battery voltage of 2.0 to 2.3 volts and one for terminal battery voltage of 1.75 to 2.7 volts. Note that at 3 ohms per thousand feet ballast, it is possible to work safely a maximum D.C. track circuit length of 8,000 feet using Curve A and 12,000 feet using Curve B. At 5 ohms per thousand feet ballast, this safely increases to a maximum track circuit length of 12,000 feet using Curve A and 18,000 feet using Curve B. In other words, by using the special DN-22BH track relay D.C. track circuits can be extended approximately 50% farther simply by maintaining closer battery terminal voltages.

Figure 2-3 is similar to Figure 2-2, except it is for the standard 4 contact DN-11.

Note that at 3 ohms per thousand feet ballast, it is possible to have a maximum track circuit length of 1,200 feet using Curve A and 3,800 feet using Curve B safely. At 5 ohms per thousand feet ballast, this safely increases to a maximum track circuit length of 2,000 feet using Curve A and 6,000 feet using Curve B.

In this case D.C. track circuits can be extended to approximately three times as far simply by maintaining closer battery terminal voltages. Note that it is much more important that the closer terminal voltages be maintained for the standard relay than it is for the special DN-22BH.

2.2.2 Limiting Resistances "X" and "R"

The value of the feed end resistor "X" is determined by: calculating the minimum amount of resistance in series with the battery that is required to protect the source voltage during occupancy.

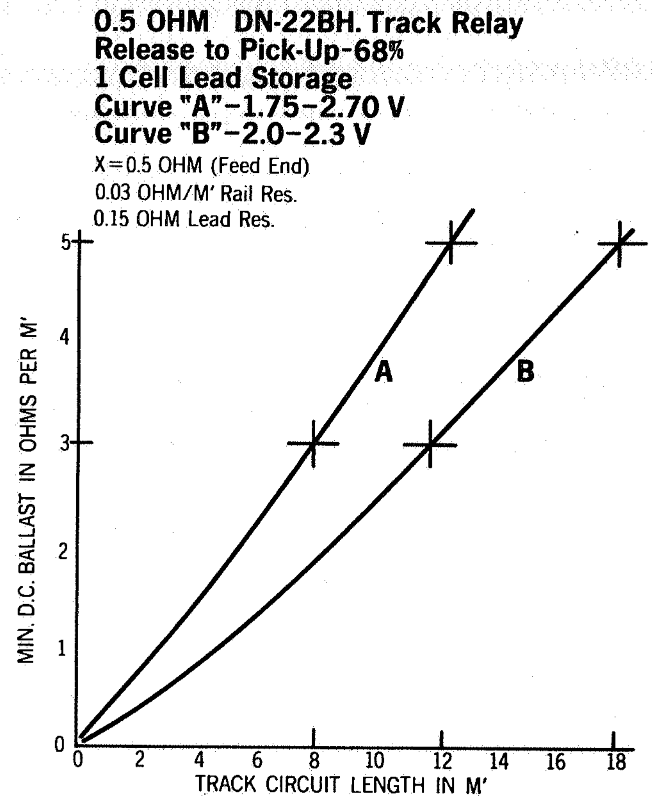


Figure 2-2. Maximum D.C. Track Circuit Length Obtainable With Poor vs Good Battery Maintenance Using a DN-22BH Track Relay.

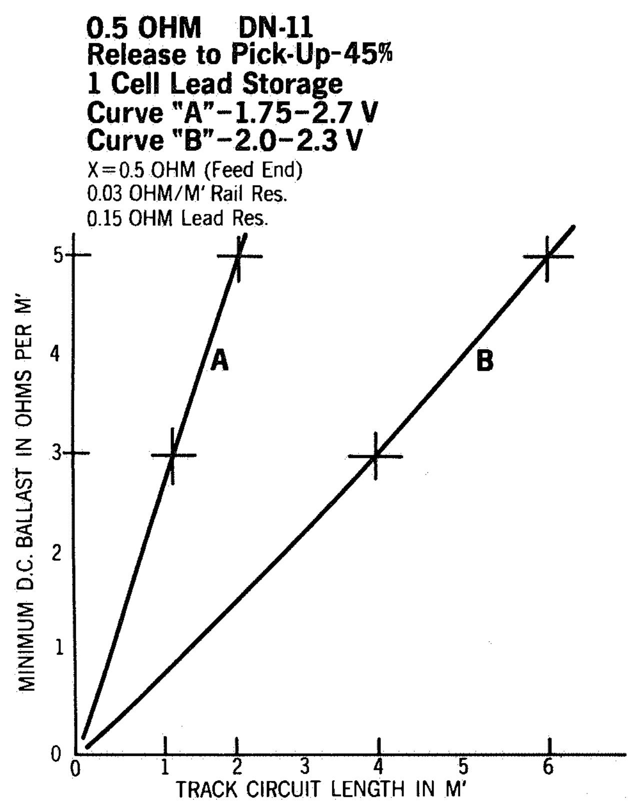


Figure 2-3. Maximum D.C. Track Circuit Length Obtainable With Poor vs Good Battery Maintenance Using a DN-11 Track Relay.

The following is a list of resistance values that have been used over the years to protect the various types of batteries against the short circuit condition of occupancy.

MINIMUM FEED END LIMITING RESISTANCE

TYPE OF BATTERY	STEADY ENERGY CIRCUITS
Lead Storage	0.5 Ohm
Nickel Storage	0.35 Ohm
Air Cell Primary	0.35 Ohm
Caustic Soda Primary	0.25 Ohm

The value at which the adjustable resistor at the relay end "R" is set is the point where the relay will just deenergize when a 0.06 ohm shunt is placed across the track (at the relay end) at a time when ballast resistance is at its minimum.

It is interesting to note that the release time of the standard DN-11 track relay, with a shunt in the circuit and without any resistance in series with this relay, is about two seconds. If we can put a resistor, equal in value to the relay coil resistance, in series with the standard DN-11 track relay, we can cut the shunt release time in half or to about one second. Additional series resistance will, of course, further reduce the shunt release time.

The release time of the high ratio of release current to working current for the DN-22BH or PN-150BH track relay with a train in the circuit and without any resistance in series with this relay is about seven tenths of a second. This quicker release of the high ratio of release current to working current for the DN-22BH or PN-150BH relay is one of several very good reasons why this type of relay should be used as the standard steady energy track relay. Again, if we can put a resistor, equal in value to the relay coil resistance, in series with this type track relay we can cut the shunt release time in half or to about thirty five hundredths of a second. Additional series resistance will, of course, further reduce the shunt release time of this type track relay.

2.2.3 Level Detection

Track relays require a certain amount of current for proper operation and this current level is identified as working current. Track relays, in the case of steady energy track circuits, require the relay current to fall to a certain level before the relay releases. This current level is identified as release current. The ratio between the release current level and the working current level is identified as level detection.

The following tabulation shows how the level detection varies for several types of track relays.

LEVEL DETECTION

STEADY ENERGY TYPE RELAY		RATIO RELEASE CURRENT TO WORKING CURRENT
DN-22BH	(2 point)	68%
PN-150BH	(2 point)	64%
DN-22	(2 point)	48%
DN-11	(4 point)	45%
DN-11	(6 point)	38%
PN-150B	(6 point)	45%

Figure 2-4 clearly shows longer track circuits can be used for a given ballast or track circuits can be operated to a lower minimum ballast for a given track circuit length with a higher percentage of level detection. The higher % level detection possible with the DN-22BH or PN-150BH track relays is another good reason why this type relay should be used as the standard steady energy track relay. In fact, it is possible to use d.c. track circuits with the DN-22BH and PN-150BH relay track relays up to about the same track lengths as is possible with coded track circuits, providing foreign current is not a problem.

As can be seen on Figure 2-4, at 3 ohms per thousand feet minimum ballast, it is possible to have track circuits or approximately 3800 feet using a standard type relay and 12,000 feet with the special DN-22BH type relay with 0.06 ohm shunting sensitivity and broken rail protection. At 5 ohms per thousand feet ballast, it is possible to have track circuits of approximately 6000 feet using the standard type relay and track circuits are possible using the special DN-22BH type relay with 0.06 ohm shunting sensitivity and broken rail protection.

Even when track circuits over 6000 feet in length are not required, note the minimum allowable ballast required for circuit operation for the two different type track relays. The standard track relay will only work to a minimum ballast resistance of 5 ohms per thousand feet at 6000 feet and still provide 0.06 ohm shunting sensitivity and broken rail protection. Whereas, the special DN-22BH type track relay can safely be used down to approximately 1.25 ohm minimum ballast for 6000 feet and still provide 0.06 ohm shunting sensitivity and broken rail protection.

Maximum Track Circuit Length
Lead Storage Battery
2.0–2.3 Volts
"A"–DN–(Rel./P.U.=45%)
"B"–DN–22BH (Rel./P.U.=68%)

X=0.5 OHM (Feed End)
0.03 OHM/M' Rail Res.
0.15 OHM Lead Res.

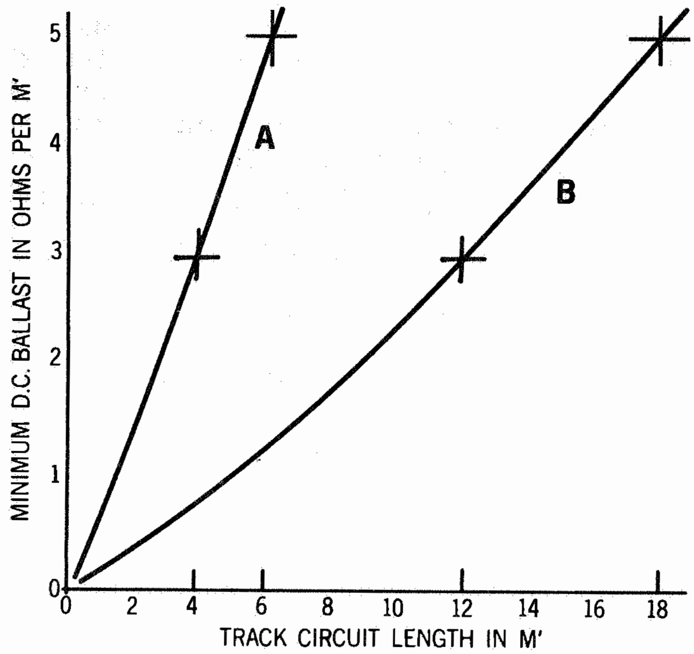


Figure 2-4.

Thus for a given length track circuit, the DN-22BH type track relay can be used on track having a much lower ballast than can a standard type relay. Consequently, ballast maintenance program is not as critical.

Since much longer track circuits are possible with a higher percentage level detection, 100 percent level detection is desirable. But it must be safe and it must be practical. The previously listed level detection figures are only 85% of the actual manufactured level detection. It is not practical to achieve and maintain 100% level detection since such things as temperature variations, component tolerance, and wear occur with time in the field.

2.2.4 Relay Resistances

The selection of the proper relay resistance also influences the maximum track circuit lengths possible for a given ballast or the minimum allowable ballast for a given track circuit length as shown below:

LEAD STORAGE BATTERY

DN-22BH Relay Resistance	Minimum Ballast in ohms per thousand feet for 6,000 feet circuit.	Maximum Track Circuit length with broken rail protection & 0.06 ohm shunting sensitivity at 3 ohms per thousand feet ballast.
0.5 ohm	1.27 ohms/M'	12,000'
1.0 ohm	1.57 ohms/M'	11,000'
2.0 ohm	1.9 ohms/M'	9,500'
4.0 ohm	2.3 ohms/M'	7,500'

2.2.5 Ballast Resistance

D.C. ballast resistance varies with moisture, type of ballast, salt content, proximity to the rails, drainage, and tie and spike conditions. When ballast is frozen, it is nearly infinity. When ties are good condition and the ballast is not in contact with the rails a minimum D.C. ballast resistance of at least 3 ohms per thousand feet could be typical; in many territories with good drainage and clean ballast, the minimum D.C. ballast resistance may be 5 or 10 ohms, and in rare cases unbelievably high. On the other hand, with cracked and dirt-filled ties, and with dirty ballast in contact with the rails, the minimum is likely to be 1 ohm. In salt flat areas, or where the rails are buried in dirt and cinders, ballast resistance may fall to less than 0.1 ohm per thousand feet.

2.2.6 Rail Resistance

The D.C. rail resistance varies with the type of bonding used as shown below:

(a) Web type bonding, with 48 inch, 2 #6 Copper, looks like approximately 0.05 ohm per thousand feet.

(b) Railhead type bonding looks like approximately 0.03 ohm per thousand feet.

(c) Welded rail looks like approximately 0.015 ohm per thousand feet.

These figures for a and b are for 39 foot rails weighing 130 pounds per yard and assumes that no rail joint bars conduct current and are approximately correct for rails of other weight than 130 pounds per yard.

2.3 BROKEN RAIL DETECTION AND SHUNTING SENSITIVITY

According to the R.S.& I., track circuits used for signaling must provide broken rail detection and 0.06 ohm shunting sensitivity. WABCO interpretates the R.S. & I. requirements on broken rail protection as that the track relay shall be in the de-energized position when a rail is broken or removed except when the break occurs:

1. Within a shunt fouling circuit of a turnout or crossover.

2. Between the end of a rail and track circuit connector.

3. Within the limits of the rail joint bond or appliance.

The next consideration must be to insure that a track circuit will work properly under all the required conditions, and provide the broken rail protection and 0.06 ohm shunting sensitivity required.

To do this, WABCO employs a Master Curve Sheet, Figure 2-5, for each set of conditions to insure proper working with the proper limitations.

The Master Curve Sheet uses minimum ballast in ohms per thousand feet as the base coordinates and R in ohms as the vertical coordinates. R is defined as the total resistance at the relay end of the circuit, including the track relay resistance, track leads and series adjustment resistance

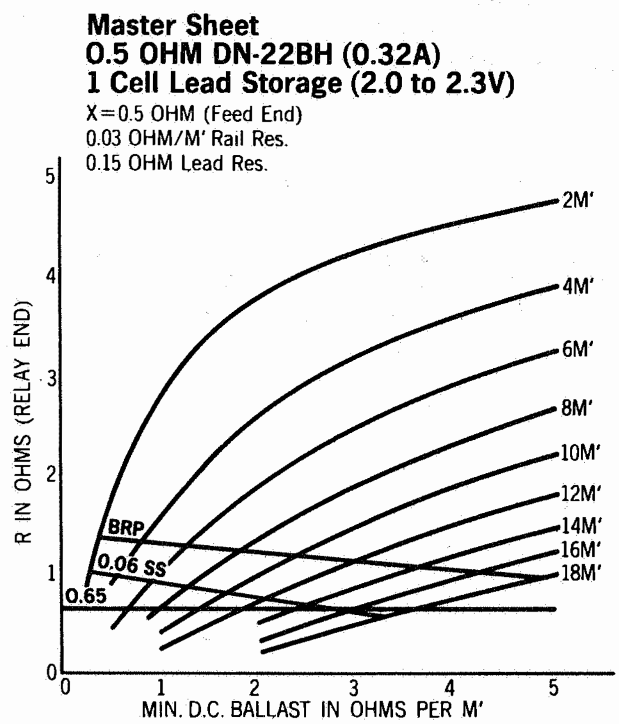


Figure 2-5

At the top of the Master Sheet, the given set of conditions for which the curve was made up are given. This particular curve is for a 0.5 ohm DN-22BH track relay that requires 0.32 for proper working. The battery is a single cell of lead storage with 2.0 volt minimum and a 2.3 ampere volt maximum as previously described in this section under "Source Voltage". A 0.5 ohm resistance X, including track leads, is used in series with the battery at the feed end of the circuit to limit the occupied current level as described under "Limiting Resistance "X" and "R". The D.C. rail resistance is 0.03 ohm per thousand feet for railhead type bonding as described under "Rail Resistance". The lead resistance considered is 0.15 ohm at both ends of the circuit.

If any of the above stated conditions change, then another Master Sheet must be made up.

A calculation is then made for a given length and a selected value of minimum ballast. This is to determine the maximum amount of resistance in ohms at the relay end of the circuit, R, that can be used in the circuit and still get working current, 0.320A, in the track relay with minimum battery voltage, 2.0 volts. The same calculation is repeated for three or four points of minimum ballast to obtain sufficient values of R. This permits plotting of a curve for the specific length such as two thousand feet, 2M'. The same set of calculations is repeated for as many lengths as is desirable, in this case 2M', 4M', 6M', 8M', 10M', 12M', 14M', 16M', and 18'.

With this curve and the knowledge of minimum expected ballast and length of circuit, the proper value for R can be read off that will insure working current in the track relay at that minimum ballast and at minimum battery cell voltage.

Having considered the factors required to get the working current into the track relay under the worst expected conditions, now the limitations must be introduced. The first limitation, previously covered is rather obvious. That is, if R includes track relay resistance, track lead resistance and series adjustment resistance, then R can never be less than 0.65 ohm (0.5 ohm track relay resistance plus 0.15 ohm track lead resistance). So the first limitation drawn is a straight line across the curve at the 0.65 ohm value for R. This means that the circuit cannot be adjusted properly for any part of the curves that extend below the 0.65 ohm line.

The second limitation to consider is the 0.06 ohm shunting sensitivity. This simply means that an 0.06 ohm train shunt, anywhere in the confines of the track circuit limits, must release the track relay.

The 0.06 ohm shunting sensitivity calculation is a fairly simple to make since it is made at infinite ballast.

The shunting sensitivity is poorest at the end of the circuit having the lower value of total resistance connected to the rails. Of course, if the circuit is balanced (X = R), then each end of the circuit will provide the same (poorest) sensitivity. Since the value of R isn't normally known to determine the value two calculations normally made: one with the 0.06 ohm shunt at the feed end; and one with the 0.06 ohm shunt at the relay end.

With the 0.06 shunt at either end of the circuit and with maximum battery voltage, 2.3 volts for lead storage (see paragraph 2.2.1), and with infinite ballast, the minimum value of R in ohms is determined that insures less than the release current, 0.218 ampere, in the track relay. The higher value of R in ohms, of the two calculations for each length, is then cross plotted on the Master Sheet and is identified on this curve as 0.06SS. This means that the circuit cannot be adjusted properly to provide 0.06 ohm shunting sensitivity for any part of the curves that extend below the 0.06SS curve.

The third limitation to consider is the broken rail protection. This simply means that a rail break that occurs must release the track relay.

Unfortunately, there is no easy way to determine what ballast is most serious when a broken rail occurs in the circuit. So a rather laborious calculation is required. It is obvious that if the ballast were infinite, there would be no way for the current to leak around the break. It is also obvious that if the ballast were zero, the track circuit would be short circuited and energy would not be able to be retained in the track relay.

In performing the calculations to find broken rail protection, the minimum amount of resistance that can be put in the circuit must be determined and yet be certain that the track relay will release. Once having determined the minimum allowable resistance in ohms, this must be cross plotted on the Master Sheet, Figure 2-5 for each length.

This means the circuit cannot be adjusted properly to provide broken rail protection for any parts of the curves that extend below the BRP curve.

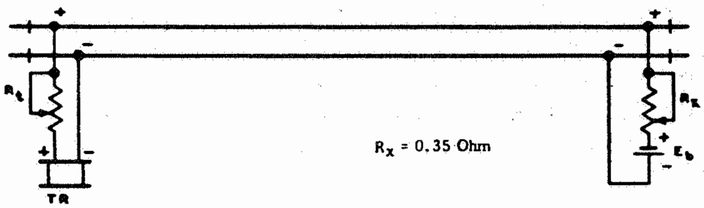
The limiting curve, either BRP, 0.06SS or 0.65, that requires the most resistance determines the maximum circuit length for a specific ballast.

2.4 ADJUSTMENT OF D.C. TRACK CIRCUITS

After this Master Sheet is complete, a Track Circuit Adjustment Table is prepared as shown on Figure 2-6. On each Track Circuit Adjustment Table, the type of relay, voltage source, rail resistance, lead resistance used in the table preparation is spelled out. It states adjustments in accordance with this table, provides 0.06 ohm shunting sensitivity and broken rail protection.

It should be noted, as it is stated previously, that the adjustment of a D.C. track circuit is made when ballast resistance is at the minimum value experienced for that track circuit. The reason for this requirement is that to begin with when adjusted the working to drop away voltage ratio across the track relay is relatively small due to circuit design, usually in the order of two to one (2:1) or three to one (3:1). This value is normally obtained when the ballast resistance is at its minimum. When ballast resistance goes higher (when it is dry) there is less ballast leakage resulting in a higher working voltage at the relay (amount dependent on track circuit length and other variables). In either case, the track circuit continues to operate.

TRACK CIRCUIT ADJUSTMENT TABLE
NON-CODED D. C. TRACK CIRCUIT CONTROL



TR = 0.5 Ohm Style DN-22BH or PN-150BH Min. Working 0.320 Ampere
E_b = 1 Cell Lead Storage
Rail Resistance 0.03 Ohm/M ft.
Min. Resistance to Shunt Track Relay 0.06 Ohm
Broken Rail Protection
Table based on 0.15 ohm total lead resistance (including track leads and case wiring) at each end of track circuit.

Note:
Conventional type track circuits are not normally recommended for lengths over 6000 feet, unless there is no possibility of foreign current.

ADJUSTMENT TABLE FOR MINIMUM D. C. BALLAST

Length Track Circuit	Min. R_t Ohms	Min. D. C. Ballast Ohms/M ft.	TR Amps. Dry at E_b = 2.3V
12000	0.45	2.97	1.15
11000	0.49	2.68	1.15
10000	0.51	2.38	1.15
9000	0.54	2.10	1.15
8000	0.56	1.81	1.15
7000	0.59	1.55	1.15
6000	0.60	1.27	1.15
5000	0.63	1.04	1.15
4000	0.65	0.80	1.15
3000	0.68	0.56	1.15
2000	0.71	0.33	1.15
1000	0.74	0.15	1.15

ADJUSTMENT TABLE FOR MINIMUM D.C. BALLAST OF 3.0 OHMS/M FT.

Length Track Circuit	R_t Ohms	TR Amps. Dry at E_b = 2.3V
12000	0.47	1.115
11000	0.61	1.050
10000	0.81	0.960
9000	1.01	0.920
8000	1.22	0.850
7000	1.48	0.790
6000	1.78	0.730
5000	2.13	0.665
4000	2.53	0.600
3000	3.00	0.535
2000	3.56	0.475
1000	4.25	0.420

ADJUSTMENT TABLE FOR MINIMUM D. C. BALLAST OF 5.0 OHMS/M FT.

Length Track Circuit	R_t Ohms	TR Amps. Dry at E_b = 2.3V
12000	1.10	0.845
11000	1.29	0.800
10000	1.51	0.760
9000	1.75	0.715
8000	2.00	0.670
7000	2.25	0.630
6000	2.55	0.585
5000	2.85	0.545
4000	3.20	0.510
3000	3.60	0.470
2000	4.05	0.435
1000	4.55	0.400

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Figure 2-6

On each D.C. table three sets of data are shown, one for 3 ohms per thousand feet minimum ballast, one for 5 ohms per thousand feet minimum ballast, and one set that shows the minimum ballast a circuit length can safely be worked.

However, if the track circuit was adjusted at a value higher than the minimum ballast resistance value and the ballast resistance falls, the working voltage at the relay also falls, due to the ballast leakage increase. Since the working to drop-away voltage ratio was small, and with the introduction of more ballast leakage the resulting voltage at the track relay could fall to (or below) the drop-away value, thereby causing the relay to deenergize. The result is an unreliable track circuit which deenergizes when its ballast resistance falls, but due only to improper adjustment.

It becomes apparent that to have a reliable D.C. track circuit it is necessary that it be adjusted when the ballast resistance is at its minimum and that in order to get broken rail detection and 0.06 ohm shunting sensitivity that it be adjusted following the parameters as stated on the appropriate track circuit table.

The only consideration remaining is when and why does the ballast resistance reach its minimum value. The actual minimum ballast resistance condition usually occurs at the beginning of a rainfall. The reason for this occurrence is that the rain combines with the conductive earth salts to form an electrolyte solution which shunts the track circuit current. However, as the rain continues the conductive earth salts are washed away by the rainfall. Rainwater being a poor conductor in itself causes the ballast resistance to increase somewhat above the value experienced at the beginning of the rainfall.

SECTION III

AUDIO FREQUENCY OVERLAY (AFO) TRACK CIRCUIT

3.1 INTRODUCTION

The purpose of the Audio Frequency Overlay Track Circuit is to provide a means of vital train detection, 0.06 ohm shunting sensitivity, and which would be supplemental to those already present in the railroad mainline signal system. Furthermore, this circuit does not have need of insulated joints.

It is NOT the intent of AFO type track circuits to provide the broken rail protection required for signaling purposes, but that function is the responsibility of the primary track circuit that the audio frequency overlay (AFO) is superimposed upon.

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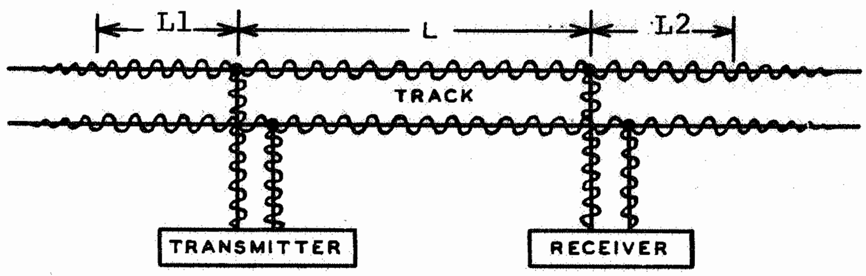
3.2 TRACK CIRCUIT PARAMETERS (Reference Figure 3-1)

The physical length of the AFO track circuit is established by the area between the placement of the transmitter's leads and the receiver's leads. However, since there are no insulated joints to electrically isolate the circuit, the electrical length varies with transmitter output and receiver sensitivity, operating frequency, ballast resistance, and rail impedance.



L = Physical Length

$L + L_1 + L_2$ = Electrical Length

Figure 3-1. AFO Track Circuit Signal

The electrical length of the track circuit is equal to the Physical Length distance between transmitter's and receiver's track leads, (L) plus the amount of spillover (L1) and(L2) past the transmitter and receiver. The total electrical length of the AFO Track Circuit corresponds to the area between the point at the receiver end where 0.06 ohm shunt causes the receiver relay to deenergize and the corresponding point at the transmitter end.

3.2.1 Transmitter Output and Receiver Sensitivity

When transmitter power is higher, the receiver's sensitivity is adjusted to a lower level. This results in a decrease in the lengths of L1 and L2.

Conversely with lower transmitter power, the receiver's sensitivity must be increased which results in the length of L1 and L2 to increase.

The main factor in determining the transmitter power required is the track circuit length to be worked. The limiting factors of operating frequency, track ballast swing and rail impedance must all be considered to determine the safe length of track that can be worked while maintaining 0.06 ohm shunting sensitivity.

3.2.2 Operating Frequency

Longer track circuits can be worked using lower AFO frequencies. However, the same limiting factors previously mentioned must be considered to insure shunting sensitivity will be maintained.

Lower frequencies will increase the length of L1 and L2 and conversely higher frequencies will shorten their length.

3.2.3 Ballast Resistance

Ballast resistance governs the maximum length of a track circuit. The higher the minimum value experienced, the longer the track circuit may be used. Conversely the lower the minimum value experienced, the shorter the track circuit that may be used. Again, all other parameters must be considered.

Length of L1 and L2 (amount of spillover) will be longest when ballast resistance is at its minimum (when wet). Conversely, these lengths will be at a minimum when ballast is at it's highest resistance (dry or frozen).

3.2.4 Rail Impedance

Rail Impedance affects the maximum length obtainable for the track circuit. Higher rail impedances result in shorter track circuit lengths that can be worked. Conversely, lower rail impedance allow longer distanced to be worked.

Length of L1 and L2 (amount of spillover) will be the longest when rail impedance is the lowest and shortest when rail impedance is highest.

Again all other parameters must be considered.

3.3 SHUNTING SENSITIVITY

The application of AFO is greatly simplified since broken rail detection is furnished by the primary track circuit. The only remaining concern is that the AFO track circuit be capable of providing 0.06 ohm shunting sensitivity and that it sustains relay energization when no train is present. Both of these conditions must remain satisfied throughout the entire range of ballast resistance encountered to have a safe and reliable track circuit.

The AFO equipment is designed considering all of the track circuit parameters discussed previously (3.2 AFO TRACK CIRCUIT PARAMETERS) and, as can be seen through the description, that changing one variable can cause several desirable results while creating a couple not so desirable. All that can be done is select an area where not too much is sacraficed and yet reap the best benefits obtainable. AFO design in summary looks at all the "trade-offs" and places a "design window" on the area which will provide the best service to the user.

3.3.1 Loss of Shunting Sensitivity

Shunting sensitivity can be lost due to:

1. Excessive Rail Film
2. Improper Installation Adjustment
   a) Improper Receiver sensitivity setting
   b) Excessive Transmitter Power (Beyond ability to adjustment of the Sensitivity control with a 0.06 ohm shunt applied).
   c) Combination of (a) and (b).
   d) Performing adjustment when ballast is wet.

3.3.2 Maintaining Shunting Sensativity and a Reliable Track Circuit

Excessive rail film should not be present where AFO is being applied. Since AFO is usually applied on mainline there is usually sufficient rail traffic to offer little chance for rail film to build up.

Before an installation is made two considerations must be made: (1) Maximum and Minimum track ballast encountered (/M') and (2) track circuit length based on transmitter output power and frequency.

Since the maximum energy loss will be when the ballast resistance is at a minimum (when wet), the transmitter's power and frequency must be sized up to ensure it will work the length intended. <u>Maximum track circuit length obtainable is based on the MINIMUM ballast resistance encountered and the operating frequency (See Table 3-1).</u>

CAUTION

It is electrically possible to keep the relay energized at lengths greater than that shown. However, it would require the receiver's sensitivity to be adjusted to a level too high to provide 0.06 ohm shunting sensitivity. Resetting the receiver's sensitivity to the proper level would result in un-reliable relay energization when no train is present. Therefore, be certain to stay within the guidelines of Table 3-1.

3.4 ADJUSTMENT OF AFO TRACK CIRCUITS

Once the transmitter power and frequency are established (according to Table 3-1), the equipment is installed, having the batteries fully charged and several days of dry weather (or a day when ballast is frozen) proceed as follows:

1. Connect all AFO units to rails.
2. Place an 0.06 ohm shunt across the receiver leads at the case, or across the rails using tight clamps.
3. Adjust the receiver sensitivity control until the track relay just releases.
4. Remove the 0.06 ohm shunt and observe that the relay picks-up.
5. Place the shunt at the transmitter's leads - relay should deenergize.
6. Remove shunt, relay should pick-up.

Unlike conventional DC track circuits, having only a two to one (2:1) or three to one (3:1) working to drop away voltage ratio, AFO has a working to drop away ratio in the order of fourteen to one (14:1) and when adjusted as set forth by these guidelines, provides sufficient safe overenergization that it's extremely unlikely for relay deenergization to take place when it begins to rain as happens, on occasion, with DC Track Circuits.

3.5 APPLICATION OF AFO TRACK CIRCUITS

A typical AFO installation consists of two AFO Transmitters and two AFO Receivers of different frequencies connected as shown in Figure 3-2.

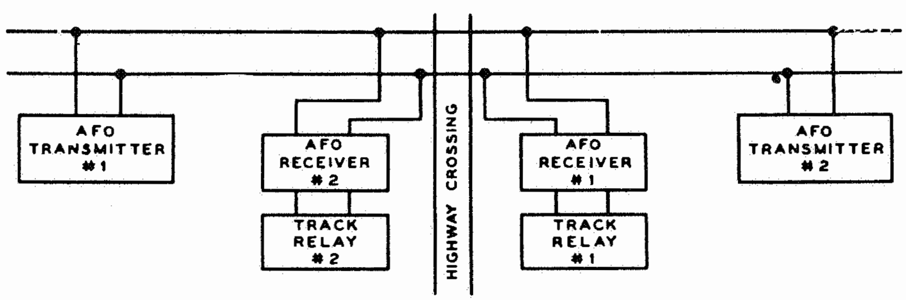


Figure 3-2. Highway Crossing Protection Showing Multiple Connection Installation.

For multiple crossing frequencies they should be staggered as set forth in Service Manual 5906 (AFO II) or 5906A AFO Repackage. See the appropriate Service Manual for detailed descriptions on application and use.

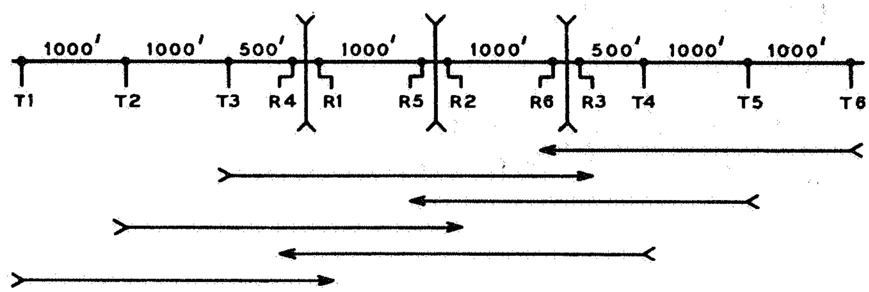


Figure 3-3. AFO Circuits used for Three or Less Adjacent Highway Crossings.

TABLE 3-1.

MAXIMUM TRACK CIRCUIT LENGTH IN FEET VS. OPERATING FREQUENCY FOR AFO II OVERLAY

	LOW POWER UNIT 30% OUTPUT		LOW POWER UNIT 100% OUTPUT		HIGH POWER UNIT 100% OUTPUT	
	MINIMUM BALLAST		MINIMUM BALLAST		MINIMUM BALLAST	
(Hz) OPERATING FREQUENCY	3 OHMS	5 OHMS	3 OHMS	5 OHMS	3 OHMS	5 OHMS
885	2300	2700	4200	5100	5300	6500
930	2300	2700	4200	5100	5300	6500
1050	2100	2400	3900	4700	4900	6000
1120	2000	2300	3700	4500	4600	5700
1330	1800	2000	3300	4000	4200	5200
1420	1700	1900	3200	3900	4100	5000
1860	1500	1600	2700	3300	3500	4300
2140	1300	1400	2500	3000	3200	3800
2540	1100	1200	2200	2700	2900	3500
2720	1000	1100	2100	2600	2800	3300
3360	800	900	1900	2200	2400	2900
3410	800	900	1900	2200	2400	2900
4565	800	800	1700	1800	2000	2400
5090	700	700	1500	1700	1900	2300
6180	600	600	1300	1500	1700	1900
6330	600	600	1200	1400	1600	1800

NOTES:

1. Example - The maximum track circuit length using a 1050Hz low power transmitter on 100% output setting at 5 ohms minimum ballast is 4700 ft.
2. Chart is based on receiving 5 millivolts across a .06 ohm shunt at the receiver connections.

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