



# Orientation

Course 100

PARTICIPANT GUIDE

 SIGNALS TRAINING CONSORTIUM

# Orientation

---

## Participant Guide

Signals Maintenance Training Consortium

COURSE 100

*September 2017 Draft*

PREVIEW ONLY

**Disclaimer:** This module is intended to educate employees of transit agencies that have agreed to voluntarily participate in the Signals Maintenance Consortium. It is intended only as informal guidance on the matters addressed, and should not be relied upon as legal advice. Anyone using this document or information provided in the associated training program should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of care in any given circumstances. The Signals Consortium, its participating agencies and labor unions, as well as the Transportation Learning Center, make no guaranty or warranty as to the accuracy or completeness of any information provided herein. The Signals Consortium, its participating agencies and labor unions, as well as the Transportation Learning Center, disclaims liability for any injury or other damages of any nature whatsoever, directly or indirectly, resulting from the use of or reliance on this document or the associated training program.

NOTE: All images contained within this document were contributed by Signals Training Consortium members unless otherwise noted.

PREVIEW ONLY

TABLE OF CONTENTS	PAGE
<b>How to Use the Participant Guide.....</b>	<b>vi</b>
<b>MODULE 1: INTRODUCTION TO SIGNALING AND TRAIN CONTROL.....</b>	<b>1</b>
1-1 OVERVIEW .....	2
1-2 EVOLUTION OF RAILROAD SIGNALING.....	3
1-3 SAFETY AND RESPONSIBILITIES .....	10
1-4 GOVERNING AGENCIES AND AUTHORITIES.....	13
1-5 PRINCIPLES OF FAIL-SAFE AND VITAL AND NON-VITAL .....	14
1-6 POSITIVE TRAIN CONTROL .....	15
1-7 SUMMARY.....	16
<b>MODULE 2: ROADWAY WORKER PROTECTION AND ON-TRACK SAFETY... </b>	<b>17</b>
2-1 OVERVIEW .....	18
2-2 RAIL ROADWAY WORKER PROTECTION.....	19
2-3 ON-TRACK SAFETY .....	23
2-4 COMMUNICATION .....	28
2-5 REDUCING PERSONAL RISK AND INJURY ON YOUR JOB SITE .....	30
2-6 SUMMARY.....	35
<b>MODULE 3: SIGNAL SYSTEM COMPONENTS.....</b>	<b>36</b>
3-1 OVERVIEW .....	37
3-2 TRACK CIRCUITS .....	38
3-3 SWITCHES AND DERAILS.....	41
3-4 TRAIN STOPS .....	43
3-5 GRADE CROSSINGS .....	44
3-6 SIGNALING .....	47
3-7 INTERLOCKINGS .....	48
3-8 SUMMARY.....	49
<b>MODULE 4: RELAYS AND RELAY LOGIC .....</b>	<b>50</b>
4-1 OVERVIEW .....	51
4-2 RELAY TERMINOLOGY.....	52
4-3 TYPES OF RELAYS .....	55

4-4 SYMBOLS AND NOMENCLATURE .....	62
4-5 RELAY LOGIC AND CIRCUIT DIAGRAMS.....	65
4-6 SUMMARY.....	74
<b>MODULE 5: INTRODUCTION TO PRINTREADING .....</b>	<b>75</b>
5-1 OVERVIEW .....	76
5-2 CHARACTERISTICS OF PRINTS .....	77
5-3 SYMBOLS .....	83
5-4 NOMENCLATURE.....	91
5-5 SUMMARY.....	94
<b>MODULE 6: PREPARATION FOR INSPECTION AND MAINTENANCE .....</b>	<b>95</b>
6-1 OVERVIEW .....	96
6-2 BASICS OF SIGNALS MAINTENANCE.....	97
6-3 TOOLS AND EQUIPMENT FOR MAINTENANCE .....	107
6-4 RECORD KEEPING.....	113
6-5 SUMMARY.....	114
<b>MODULE 7: GUIDELINES AND RECOMMENDED PRACTICES .....</b>	<b>115</b>
7-1 OVERVIEW .....	116
7-2 RECOMMENDED CHARACTERISTICS FOR JUMPERS .....	116
7-3 REMOVING SIGNAL EQUIPMENT FROM SERVICE.....	119
7-4 RETURNING SIGNAL EQUIPMENT TO SERVICE .....	122
7-5 SUMMARY.....	124
<b>GLOSSARY.....</b>	<b>125</b>

PREVIEW ONLY

## LIST OF FIGURES

Figure 1.1 Santa Fe timetable from 1889 (Wikipedia).....	3
Figure 1.2 Train Order Document from Southern Railway Company ( <a href="http://williamfcody.bbhc.org/">http://williamfcody.bbhc.org/</a> ).....	3
Figure 1.3 Fixed Signal (Source: Wikipedia).....	4
Figure 1.4 Disc and Cross Bar Signal (Source: <a href="http://www.trainweb.org/">http://www.trainweb.org/</a> ).....	4
Figure 1.5 Mechanical Semaphore - Courtesy MetroNorth.....	4
Figure 1.6 Semaphore Aspect Meanings.....	4
Figure 1.7 Tower and Tracks at Deval Interlocking, Des Plaines (Wikipedia).....	6
Figure 1.8 Strong Arm Mechanical Interlocking Machine- Courtesy LIRR.....	7
Figure 1.9 Interlocking Bed- Courtesy Wikipedia.org.....	7
Figure 1.10 Unoccupied Track Circuit (Wikipedia).....	8
Figure 1.11 Occupied Track Circuit (Wikipedia).....	8
Figure 1.12 CBTC Illustration.....	9
Figure 2.1 APTA Rail Standard Roadway Worker Protection Program Requirements.....	21
Figure 2.2 Job Brief Form from TriMet, Portland, Oregon.....	26
Figure 2.3 Pinch Points and the Wrong Way to Stand Near a Switch - Courtesy LIRR.....	30
Figure 2.4 Bonding Wires as a Trip, Slip and Fall Hazard - Courtesy LIRR.....	30
Figure 2.5 Proper Ladder Angle - OSHA©.....	32
Figure 2.6 Three Points of Contact - OSHA©.....	32
Figure 2.7 Full-body Harness (Source: <a href="http://www.1staidssupplies.com/">http://www.1staidssupplies.com/</a> ).....	33
Figure 3.1 Unoccupied Track Circuit.....	38
Figure 3.2 Track Circuit Occupied by Train.....	39
Figure 3.3 Labeled Components of a Railroad Switch.....	42
Figure 3.4 Switch Point Derail.....	42
Figure 3.5 Train Stop.....	43
Figure 3.6 Dragging Equipment Detector.....	43
Figure 3.7 Passive Highway Grade Crossing with a Crossbuck Mounted on a Mast.....	44
Figure 3.8 Active Highway Grade Crossing with Automatic Warning devices Labeled.....	45
Figure 3.9 Inter-relation of Carborne, Wayside and CIL Equipment.....	47
Figure 3.10 Interlocking near MBTA Orient Heights Station in Boston.....	48
Figure 4.1 Vane Relay for AC Track Circuit - Courtesy MBTA.....	51
Figure 4.2 A Group of Alstom B1 Relays - Courtesy MBTA.....	51
Figure 4.3 Examples of Non-vital Relays ©Alstom ©GTE.....	52
Figure 4.4 Basic Components of a Relay –courtesy MBTA.....	53
Figure 4.5 GRS/Alstom B-1 Relay with Two Coils - Courtesy MBTA.....	53
Figure 4.6 Dependent Relay Contacts –courtesy MBTA.....	54
Figure 4.7 Independent Relay Contacts.....	54
Figure 4.8 Examples of Ansaldo Shelf-mounted Relays –Courtesy MBTA.....	55
Figure 4.9 Typical B-1 and B-2 Plug-in type relays: Single and double slot ©Alstom.....	55
Figure 4.10 Typical Plug-in Single and double slot relays ©Ansaldo.....	55
Figure 4.11 Relay with Matching Plugboard.....	57
Figure 4.12 Manufacturer's Nameplate on Relay.....	58
Figure 4.13 Alphanumeric System of L Type Relay ©US&S (now Ansaldo).....	60
Figure 4.14 US&S L Type Relay ©US&S (now Ansaldo).....	60

Figure 4.15 ©US&S, now ©Ansaldo, Backplate Numbering System.....	60
Figure 4.16 Heel Front Back Configurations ©Alstom.....	61
Figure 4.17 Plug Board ©Alstom.....	61
Figure 4.18 Plug Board Numbering System ©Alstom.....	61
Figure 4.19 Coil and Contact Numbering System.....	61
Figure 4.20 Switch Correspondence Circuit .....	62
Figure 4.21 Contact Configurations Drawn in Straight Line and Drop Line.....	65
Figure 4.22 Circuit Polarity for AC or DC, 12 Volts –Courtesy MBTA.....	66
Figure 4.23 AND / OR Conditions in a Relay Circuit –Courtesy MBTA.....	67
Figure 4.24 Stick Circuit.....	68
Figure 4.25 Overall Drawing Showing Track Circuits for Context - Courtesy MBTA.....	69
Figure 4.26 Single Relay Controlling Two Signal Aspects –Courtesy MBTA.....	70
Figure 4.27 Home and Distant Track Circuits are Unoccupied–Courtesy MBTA.....	70
Figure 4.28 Red Signal with Home Relay De-energized –Courtesy MBTA.....	70
Figure 4.29 Distance Track Circuit is Occupied –Courtesy MBTA.....	71
Figure 4.30 Front Contact of Track Relay Energizing the Home Relay Coil–Courtesy MBTA .	71
Figure 4.31 Switch Correspondence Circuit .....	72
Figure 5.1 Cover of Bound Prints for the Central Instrument House at Wonderland Station.....	77
Figure 5.2 Index Showing Page Numbers and Page Titles –Courtesy MBTA.....	78
Figure 5.3 Symbols of Components Represented on Prints –Courtesy MBTA.....	79
Figure 5.4 Title Block –Courtesy Long Island Rail Road.....	80
Figure 5.5 Showing Grid Designations –Courtesy MBTA.....	81
Figure 5.6 Elements of a Print –Courtesy MBTA.....	82
Figure 5.7 Highway Grade Crossing Layout –Courtesy LIRR.....	88
Figure 5.8 Single Rail AC Track Circuit.....	89
Figure 5.9 Queens 1 Interlocking Circuit –Courtesy LIRR.....	90
Figure 5.10 Section of Block Layout between Two Stations –Courtesy MBTA.....	91
Figure 5.11 Nomenclature on Print –Courtesy MBTA.....	92
Figure 6.1 Courtesy of the Metropolitan Rail Corporation .....	106
Figure 6.2 Torque Wrench Kit ©Railroad Signal International.....	108
Figure 6.3 Relay Testnut Wrench ©Safetran.....	108
Figure 6.4 Cup Gauge.....	109
Figure 6.5 Spring Gauge.....	109
Figure 6.6 Feeler Gauge.....	109
Figure 6.7 Obstruction Gauge.....	109
Figure 6.8 Shunt Unit With Clamps, Cable, And Resistor Bracket.....	110
Figure 6.9 Analog Multimeter ©Simpson.....	110
Figure 6.10 Digital Multimeter ©Fluke .....	110
Figure 6.11 Oscilloscope.....	111
Figure 6.12 Monthly Signal House Inspection Sheet –Courtesy CATS-LYNX.....	113
Figure 7.1 Train Derailed Due to Unauthorized Use of Jumper .....	118
Figure 7.2 Sample Form Used Authorizing the Removal of Equipment from Service .....	121
Figure 7.3 Typical Shunt Placement at a Two-Track Grade Crossing .....	122
Figure 7.4 Rear Half of Automobile after Collision at Grade Crossing, McLean, IL, in 1999	123

## How to Use the Participant Guide

### Purpose of the Course

The purpose of the *Orientation* course is to assist the participant in being oriented to signaling and train control.

### Approach of the Book

Each course module begins with an outline, a statement of purpose and objectives, and a list of key terms. The *outline* will discuss the main topics to be addressed in the module. A list of *key terms* identifies important terminology that will be introduced in this module. *Learning objectives* define the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the module. *Review exercises* conclude each module to assist the participants in reviewing key information.

PREVIEW ONLY

# Module 1

## *INTRODUCTION TO SIGNALING AND TRAIN CONTROL*

### Outline

- 1-1 Overview**
- 1-2 Evolution of Railroad Signaling**
- 1-3 Safety on the Job**
- 1-4 Governing Agencies and Authorities**
- 1-5 Principles of Fail-safe and Vital and Non-vital**
- 1-6 Positive Train Control**
- 1-7 Summary**

### Purpose and Objectives

The purpose of this course is to provide the participant with an overview to signaling and train control and to introduce the participant to the foundation of their work as a signal maintainer.

Following the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Explain the purpose of a signaling system
- Explain the evolution of railroad signaling
- Specify how signal maintainers are responsible for the safety of the general public
- Identify the importance of governing agency and location operating rules/policies
- Define “fail-safe”
- Explain why systems have to fail in a safe manner
- Differentiate between vital and non-vital
- Discuss future technologies, such as PTC

### Key Terms

- |  |                                |                                      |
|--|--------------------------------|--------------------------------------|
| • Aspect                                   | • Disc And Cross Bar Signal    | • Rail Safety Improvement Act (RSIA) |
| • Automatic Train Control                  | • Fail Safe                    | • Segments                           |
| • Block                                    | • Fixed Signal                 | • Semaphore                          |
| • Block System                             | • Indication                   | • Time Table System                  |
| • Closed Circuit principle                 | • Interlocking                 | • Track Circuit                      |
| • Communication Based Train Control (CBTC) | • Non-Vital                    | • Train Order System                 |
|  | • Positive Train Control (PTC) | • Vital                              |

## 1-1 OVERVIEW

Signal maintainers install, repair and maintain the signal systems that are used to direct train movements in railroad system. The new signal maintainer will soon learn that there are two words that will be repeated throughout their career. The words are **safety** and **efficiency**. The Institute of Railway Signal Engineers (IRSE) describes the twin purposes of signaling systems as:

The purpose of a signaling system is to facilitate the safe and efficient movement of trains on the railroad. Safety and efficiency do not always sit easily with each other. The fundamental safety requirements of a signaling system include keeping trains adequately separated from each and stopping (or slowing) trains where necessary to avoid potentially unsafe situations. Efficient operation of the railroad, on the other hand, is mainly about sending as many trains as possible along a given portion of track, as quickly as possible, using the minimum of infrastructure.

The main function of a signal system is therefore to set up a route for the passage of each train over the track that it is to traverse, authorize the train operator to make the movement, maintain the route while making its movement, and finally release the route (for use by other trains) after the passage of the train.

Signal maintainers develop their craft through learning on the job as well as through training programs sponsored through their employer and union. They are schooled in the stringent federal, state, and local regulations which govern railroad signal systems and, in railroad operations, including topics on electricity, electronics, and mechanics.

The participant will also see some common acronyms are used throughout this course. They are:

- APTA The American Public Transportation Association
- AREMA American Railway Engineering and Maintenance-of-Way Association
- FHWA Federal Highway Administration
- FRA Federal Railroad Administration
- FTA Federal Transit Administration
- IRSE Institution of Railway Signaling Engineers
- MUTCD Manual on Uniform Traffic Control Devices
- OEM Original Equipment Manufacturer
- PPE Personal Protective Equipment
- RTS Rail Transit System

## 1-2 EVOLUTION OF RAILROAD SIGNALING

The purpose of a railroad signaling system is to move trains efficiently and safely. Early railroads had short lines and few trains so the need to oversee traffic of these trains was minimal. As time progressed and train traffic increased, the need for traffic control was becoming paramount. Sidings, or pull off tracks were developed to divert slower trains and allowed trains to pass each other on single track operation. The **time table system** was implemented to coordinate and safely control the growing number of trains in service. The time table consisted of information on the times of each of the regular trains, the days they ran, and the stations at which opposing trains would meet or pass by each other.

As the demand for railroad travel grew and the speed of locomotives increased so did the urgency for tighter controls. The **train order system** was put in place which offered more flexibility, cut down on costly delays and enabled trains to be added to run more often. It was the telegraph patented by Samuel Morse in 1837 that enabled the more flexible train order operation that was issued on the Erie Railroad in 1851. Train orders replaced timetables and kept to a specific format so the information conveyed would be clear and concise. Train orders made it possible to add, delete and reschedule trains. However, time was a factor to allow all parties to receive the new information.

**TRAIN No. 3.**  
**Chicago to Los Angeles**  
**AND SAN DIEGO.**

Via Chicago, Santa Fe & California Ry., Chicago to Kansas City.  
 Via Atchison, Topeka & Santa Fe R. R., Kansas City to Albuquerque.  
 Via Atlantic & Pacific R. R., Albuquerque to Harlingen.  
 Via California Southern R. R., Harlingen to Los Angeles or San Diego.

PRINCIPAL POINTS	Time	Days
1. CHICAGO (Dearborn Station)	7:00 P.M.	Mon, Wed, Fri
2. CHICAGO (Archer Ave. and 3rd St.)	7:15 P.M.	Mon, Wed, Fri
3. JOLIET	8:00 P.M.	Mon, Wed, Fri
4. MORGAN (Terre Haute Street)	8:30 P.M.	Mon, Wed, Fri
5. GREENSBORO	9:00 P.M.	Mon, Wed, Fri
6. St. Matthews (Madison Street)	9:30 P.M.	Mon, Wed, Fri
7. INDIANAPOLIS	10:00 P.M.	Mon, Wed, Fri
8. CINCINNATI	11:00 P.M.	Mon, Wed, Fri
9. KANSAS CITY	12:00 P.M.	Mon, Wed, Fri
10. ALBUQUERQUE	1:00 P.M.	Mon, Wed, Fri
11. HARLINGEN	2:00 P.M.	Mon, Wed, Fri
12. LOS ANGELES	3:00 P.M.	Mon, Wed, Fri
13. SAN DIEGO	4:00 P.M.	Mon, Wed, Fri

Figure 1.1 Santa Fe timetable from 1889 (Wikipedia)

SOUTHERN RAILWAY COMPANY. TRAIN ORDER No. 73  
 Issued at 2:00 P.M. Oct 21 - 1907  
 TO CONDUCTOR AND ENGINEER Springfield, Mo.  
 Third no seventy two  
 (22) eng 254 will meet no seventy five  
 (25) eng 256 at Spencer.

Train received 3:03 P.M. Oct 20 1907  
 Given by J. H. [Name] 20th October 1907  
 J. H. [Name]

Figure 1.2 Train Order Document from Southern Railway Company (<http://williamfcody.bbhc.org/>)

# Module 2

## ROADWAY WORKER PROTECTION AND ON-TRACK SAFETY

### Outline

- 2-1 Overview
- 2-2 Rail Roadway Worker Protection
- 2-3 On-track Safety
- 2-4 Communication
- 2-5 Agency-specific Rules on Reducing Personal Risk and Injury
- 2-6 Summary

### Purpose and Objectives

The purpose of this course is to provide the participant with an introduction to the Right-of-Way (ROW) and on-track safety topics. This module should not be substituted for standard ROW safety training and policies.

At the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater related to these objectives:

- Identify purpose and various forms of roadway worker protection
- Define rail roadway worker protection
- Recognize the importance of maintaining situational awareness in the field
- Examine vital communications between dispatch/central control, other departments, and roadway workers
- Identify physical characteristics/rules in effect of your rail transportation system to reduce your personal risk and injury

### Key Terms

- CFR 214
- Fall Protection
- Foul of Track
- Job Briefing Forms
- Job Safety Briefing
- Lookout
- On-track safety
- On-track Safety Program
- Pinch Points
- Roadway Worker in Charge (RWIC)
- Trip, Slip and Fall Hazards

## 2-1 OVERVIEW

In the rail industry, the term “roadway workers” refers to any person whose work involves being on or has the potential to foul the track. Railroad policy and rules define **foul of track** as the area within four feet of the nearest rail of a railroad track, and a location on or near a railroad track where a person or equipment is close enough to be struck by passing railway equipment or items protruding from the railway equipment. Roadway workers are employees or contractors of a railroad system whose duties include inspection, construction, maintenance or repair of railroad track, bridges, roadway signal and communication systems, electrical traction systems, roadway facilities or roadway maintenance machinery on or near the track or with the potential of fouling a track. Working on or with potential to foul a rail right-of-way is dangerous work and being aware of personal safety is the best way signal maintainers can protect themselves from injuries. A worker should not foul the track unless required in the performance of their duties. Also, the roadway worker must be constantly aware of hazards on the job.



See **A Knock at your Door** video series for illustration of safety risks on the railroad:

Pt 1: <https://www.youtube.com/watch?v=31XyWpQCWRc>



Pt 2: <https://www.youtube.com/watch?v=QMpkRt9SZio>



Pt 3: <https://www.youtube.com/watch?v=gx9VVAfHefg>



### Warning: Safety Precautions!

- You are primarily responsible for your own safety.
- Expect the movement of train or equipment on any track, in any direction, and at any time.

The federal government has set into law specific guidelines to protect roadway workers while they are on the job. The regulations are widely known as **CFR 214<sup>1</sup>** and are generally adapted by many railroad agencies whether or not they are under the jurisdiction of the Federal Railroad Administration (FRA) or the Federal Transit Administration (FTA). Both FRA and the FTA are agencies within the U.S. Department of Transportation. If your agency is subject to CFR 214 Railroad Workplace Safety there is potential for fines for the roadway worker as well as the agency if those rules are violated. Under federal railroad safety laws the FRA has jurisdiction over all railroads except “rapid transit operations in an urban area that are not connected to the general railroad system of transportation”. FRA exercises jurisdiction over all railroad passenger operations, regardless of the equipment they use.

## 2-2 RAIL ROADWAY WORKER PROTECTION

Safety is at the core of the career of a signal maintainer and it should always be a priority on every project or work order. Since 2011, accidents attributed to human factors accounted for almost 40 percent of all reported train accidents, resulting in millions of dollars in damages to the United States’ railroad industry. Accidents attributed to human factors, unlike any other causes except “miscellaneous”, have also increased since 2010 as shown in Table 2.1 Percentage Frequency of All Train Accidents by Cause.

*Table 2.1 Percentage Frequency of All Train Accidents by Cause*

Cause	2009	2010	2011	2012	*2013
Human factors	34	34	37	38	37
Track & Signal defects	38	39	36	36	35
Equipment defects	14	13	12	12	11
Miscellaneous causes	14	14	16	15	16
TOTAL	100	100	100	100	100

\*January to August data

Source: FRA Safety Data <http://safetydata.fra.dot.gov>

From the FRA’s *Compliance with Railroad Operating Rules and Corporate Culture Influences*

Employees who perform their jobs in an unsafe manner usually violate operating and safety rules. Human-factors related incidents are caused, or influenced by, unsafe work behavior and attitudes, as opposed to non-behavior related factors like inclement weather or undetected faulty track. Therefore, *nearly all human-factor incidents and injuries can be associated with one or more operating or safety rule violations.*

While there are federal, local and other laws that govern the safety of railroad roadway workers, it is ultimately up to the individual worker to always be vigilant in safety.

---

<sup>1</sup> CFR is the abbreviation for **Code of Federal Regulations** and the 214 number refers to the part of the federal law where **railroad workplace safety** is addressed.

# Module 3

## SIGNAL SYSTEM COMPONENTS

### Outline

- 3-1 Overview
- 3-2 Track Circuits
- 3-3 Switches and Derails
- 3-4 Train Stops
- 3-5 Grade Crossings
- 3-6 Signaling
- 3-7 Interlockings
- 3-8 Summary

### Purpose and Objectives

The purpose of this course is to provide the participant with an orientation to the basic components of railroad signaling systems and to provide a foundation for more in-depth exploration of signal systems in this series of courses.

Following the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Identify Track Circuits
- Identify Switches and Derails
- Identify Train Stops
- Identify Grade Crossings
- Identify Signaling
- Identify Interlockings

### Key Terms

- |  |   |                          |
|--|---|--------------------------|
| • Active Highway Grade Crossing System | • Dragging Equipment Detector (DED)     | • Railroad Signal System |
| • Alternating Current Track Circuit    | • Electronic Track Circuit              | • Signal                 |
| • Audio Frequency Track Circuit        | • Highway-rail Grade Crossing           | • Switch Machine         |
| • Coded Track Circuit                  | • Interlocking                          | • Switch                 |
| • Derail                               | • Passive Highway Grade Crossing System | • Track (Rail)           |
| • Direct Current Track Circuit         | • Power Frequency Track Circuit         | • Track Circuit          |
|  |   | • Train Stop             |

## 3-2 TRACK CIRCUITS

The track circuit is the essential component of signaling. The track circuit is the means of detecting whether or not a section of track has any rail cars standing on it. Therefore, the track circuit is the basis of train detection.

A **track circuit** is an electrical series circuit comprised of a section of rail, a transmit feed or battery end, and a receiver or relay end. The rails provide a path for current to flow from an energy-producing device (transmit end) to an energy-receiving device (receiver end). In general, most track circuits operate by sensing the loss of transmitted energy at the receiver end of the track circuit.

The purpose of a track circuit is to detect the presence of a train. Track circuits can also detect broken rails which are essentially an opening in the electrical circuit; to detect the condition of rails, such as broken rails or wires; as well as to maintain the integrity of the signal system. There are, of course, other conditions that affect the track circuit such as poor ballast conditions, loss of power supply, or any failed component within the track circuit.

The fail-safe principle as discussed in Module 1 is best illustrated in the design of a track circuit. In use in North America since the 1870s, the purpose of a track circuit is to detect the presence of trains; to detect broken rails or wires; as well as to maintain the integrity of rail devices. The theory is as follows: electrical energy is transmitted along a section of the track from the feed end to the relay end that receives this particular form of electrical energy. The feed end and relay end are electrically defined by insulated rail joints, or their equivalent, at either end.

If nothing is blocking the flow of electrical energy between the feed and relay ends, then a “non-occupancy” or “unoccupied” condition results in a clear track circuit: it is safe to set a route and permit a train to proceed.

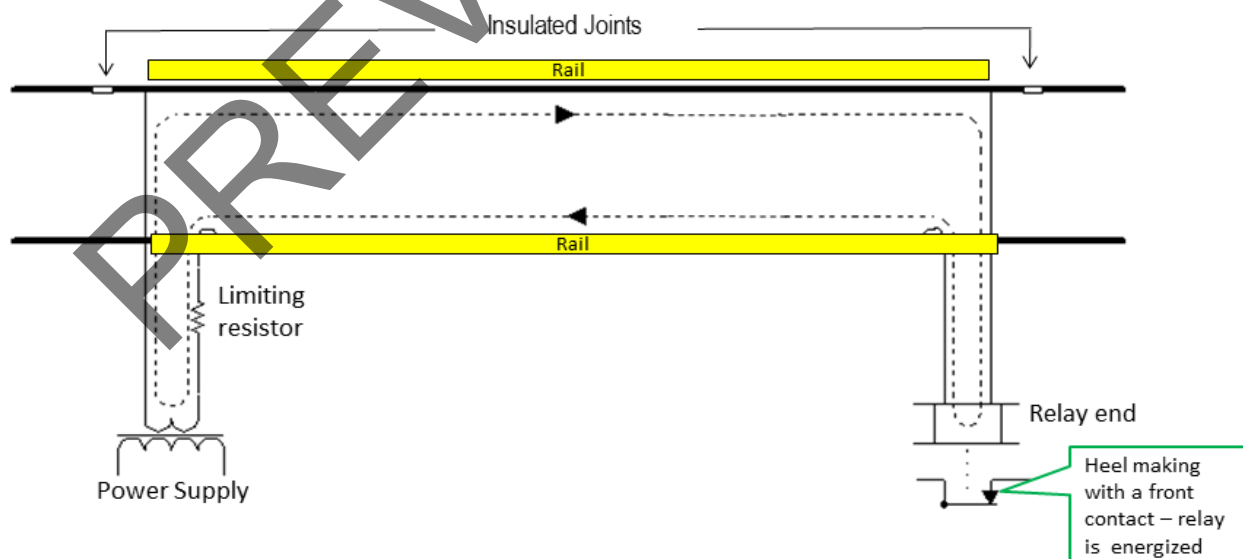


Figure 3.1 Unoccupied Track Circuit

When, as Figure 3.2 illustrates, one of the defined conditions is present on the rails in the track circuit, the flow of electricity is removed from the relay, thus the relay is de-energized, and the contact is open. In this illustration, the train's axles provide a short circuit, a process known as shunting current away from the relay. An "occupied" condition is relayed to the wayside signal and the signal shows a stop indication for that block.

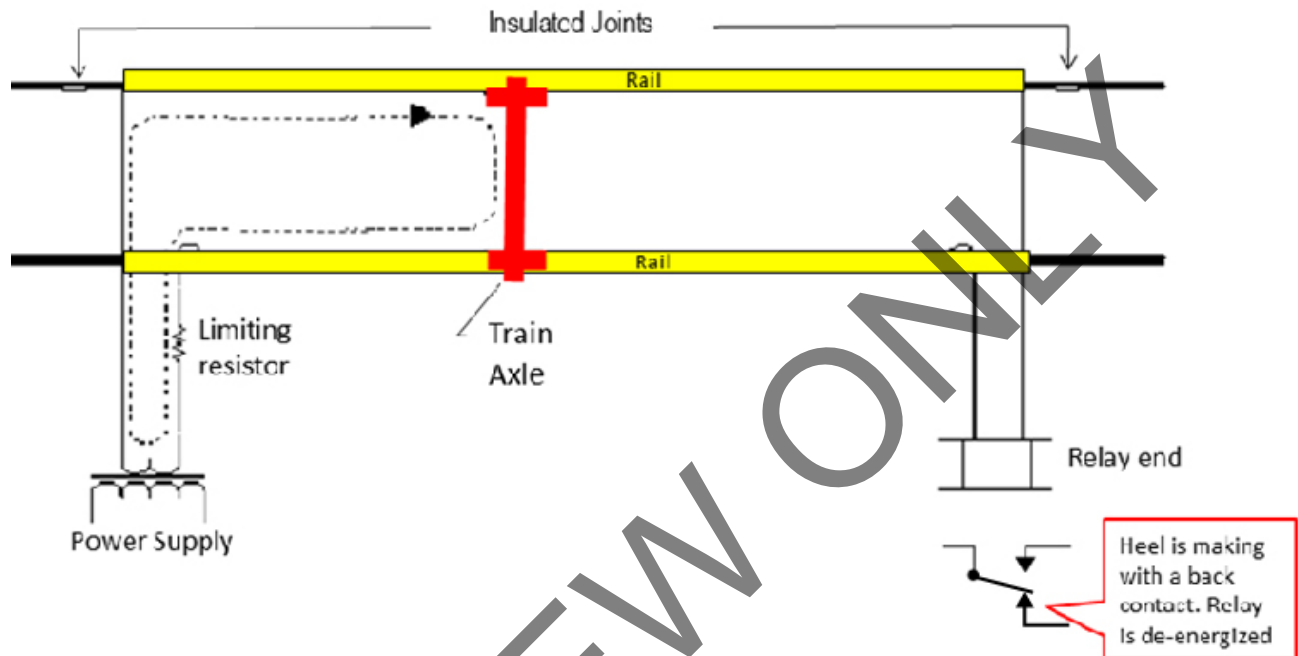


Figure 3.2 Track Circuit Occupied by Train

There are several types of track circuits and some railroads operate on different types of track circuits. The type of track circuit is designated by its source of electrical energy. In later courses, the participant will identify other types of track circuits and how to maintain and troubleshoot them. For now, there are generally five types of track circuits:

1. **Direct current (DC)** is the flow of electric current that goes in a constant direction. Direct current is typically produced by batteries and rectifiers.
2. **Alternating current or Power Frequency (AC/PF)** is an electric current that reverses its direction many times a second at regular intervals.
3. **Audio Frequency (AF)**. The AF track circuit uses a **transmitter** and a receiver. The transmitter introduces an audio signal of a specific assigned carrier frequency and modulation rate into the track through wires connected directly to the rails.
4. **Coded track circuit** can be AC or DC circuit where the energy source is transmitted as pulses through the circuit and the receiver is designed to respond to the pulses.
5. **Electronic circuit** can be AC or DC circuit that is based on microprocessor modules which are programmed for train detection and signaling.

# Module 4

## RELAYS AND RELAY LOGIC

### Outline

- 4-1 Overview
- 4-2 Relay Terminology
- 4-3 Types of Relays
- 4-4 Symbols and Nomenclature
- 4-5 Relay Logic and Circuit Diagrams
- 4-6 Summary

### Purpose and Objective

The purpose of this module is to provide the participant with the basic understanding of relays and relay logic.

Following the completion of this module, the participant should be able to complete exercises with an accuracy of 70% and greater related to these objectives:

- Define the fundamentals of relays with respect to railroad signaling
- List commonly used relay terminology
- List different types of relays used in railroad signaling
- Illustrate simple relay circuits

### Key Terms

- Armature
- Back Contact
- Coil
- De-Energized
- Dependent Contact
- Distant Relay
- Drop Line
- Energized
- Engineering Data Sheet (ED Sheet)
- Front Contact
- Heel
- Home Relay
- Independent Contact
- Nomenclature
- Original Equipment Manufacturer (OEM)
- Plug Board (Mounting Base)
- Rail Transit System (RTS)
- Registration Plate (Indexing Plate)
- Specification Sheets (Spec Sheets)
- Straight Line
- Symbols





# Module 5

## INTRODUCTION TO PRINTREADING

### Outline

- 5-1 Overview
- 5-2 Characteristics of Prints
- 5-3 Symbols
- 5-4 Nomenclature
- 5-5 Summary

### Purpose and Objectives

The purpose of this course is to provide the participant with an introduction to reading and interpreting circuit plans.

Following the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Identify components, symbols, and nomenclatures of circuit plans
- Identify indexes, revisions and track layouts
- Identify FRA or other regulations for up-to-date circuit plans in specified locations including CILs

### Key Terms

- Aspect
- Cantilever Flashing Light Signal
- Circuit Components
- Computer-Aided Design (CAD) Software
- Electrical Symbols
- Flashing Light Signal
- Flashing Light Signal And Gate Arm Mechanisms
- Grid System
- Highway-Rail Grade Crossing
- Layout Symbols
- Nomenclature
- Prints
- Revision Block
- Signal Indication
- Signal
- Symbols
- Title Block

## Layout Symbols

Layout symbols can be categorized as those for track, switches, signals, crossings, and housings. Some typical symbols are shown in the following tables.

Track Symbols	
Insulated Rail Joints Track Circuits in Both Directions	
Insulated Rail Joints Track Circuit on Left None on Right	
Insulated Rail Joints Track Circuit on Right None on Left	
Insulated Rail Joints With Bypass Device	<p>NB= NARROW BAND        WB=WIDE BAND        TJC=TUNABLE JOINT COUPLES</p>
Track Polarity and Insulated Joints	
Impedance Bonds	

Single and double tracks and switches allow trains to enter and cross over between tracks. The symbols for single switch and crossover switch types are shown in the following table.

Switch Symbols By Type		
	Single Line Plan	Double Line Plan
Single Switch	<p>SET FOR STRAIGHT ROUTE</p> <p>SET FOR DIVERGING ROUTE</p>	<p>SET FOR STRAIGHT ROUTE</p> <p>SET FOR DIVERGING ROUTE</p>
Crossover	<p>Set for straight route</p>	<p>Set for straight route</p>

Source: 2011 AREMA® C&S Manual, Part 16.2.6

**Switch fixtures** are also assigned symbols and some are shown in the following table.

Symbols for Switch Fixtures	
Switch Equipped with Switch Circuit Controller	
Switch Equipped with Spring Mechanism	
Switch Equipped with Electric Lock	

# Module 6

## PREPARATION FOR INSPECTION AND MAINTENANCE

### Outline

- 6-1 Overview
- 6-2 Basics of Signals Maintenance
- 6-3 Tools and Equipment
- 6-4 Record Keeping
- 6-5 Summary

### Purpose and Objectives

The purpose of this course is to provide the participant with an overview for work in inspecting and maintaining signal systems.

Following the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Identify procedures for testing and reporting per Government, Agency and OEM
- Restate the purpose of preventive maintenance at your agency
- Describe record keeping procedures, generally and specific to your Agency
- Identify and explain purpose and use of common tools and equipment
- Demonstrate ability to maintain and care for tools and equipment
- Identify common tools used for mechanical and electrical maintenance tests
- Identify other tools and equipment required by your Agency

### Key Terms

- Designated Signal Personnel
- Maintenance Schedule
- Preventative Maintenance Plan

### Abbreviations Used in this Module

<b>OEM</b>	Original Equipment Manufacturer
<b>AC</b>	Alternating Current
<b>DC</b>	Direct Current
<b>PTE</b>	Portable Test Equipment
<b>PM</b>	Preventative Maintenance



NIRC SIGNAL DEPARTMENT RS&D FORM  
 Maintenance Form 5  
 Monthly Battery Cell Voltage Record  
 Semi-Annual Load Maintenance Record

Remarks Attached  
 Yes  NO

Print Name: \_\_\_\_\_ ID: \_\_\_\_\_ District: \_\_\_\_\_ Subdistrict \_\_\_\_\_  
 Signature: \_\_\_\_\_ Initials: \_\_\_\_\_ Location Name: \_\_\_\_\_ MP \_\_\_\_\_  
 DOT ID: \_\_\_\_\_ Page \_\_\_\_\_ of \_\_\_\_\_

**Monthly Cell Voltage Readings**

Line	Date of Test	Battery	Total Volts	Individual Cell Voltage Readings												Water Added (Y/N)	Initials
				1	2	3	4	5	6	7	8	9	10	11	12		
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

**Semi-Annual Operational Load Record**

Line	Date	Battery	Charging Current	Individual Cell Voltage Readings												Water Added (Y/N)	Initials	
				1	2	3	4	5	6	7	8	9	10	11	12			
11																		
12																		

**Monthly Cell Voltage Readings**

Line	Date of Test	Battery	Total Volts	Individual Cell Voltage Readings												Water Added (Y/N)	Initials	
				1	2	3	4	5	6	7	8	9	10	11	12			
1																		

**NOTE:** Record battery bank charging current when "Constant Current Rectifier" is in use.

Figure 6.1 Courtesy of the Metropolitan Rail Corporation (METRA, Northeast Illinois Commuter Rail System)

## 6-3 TOOLS AND EQUIPMENT FOR MAINTENANCE

The signal maintainer is required to have a set of agency-approved tools, both common and specialized, in order to inspect and maintain signal systems. A standard tool bag for a signal maintainer may be comprised of the following tools:

- Adjustable wrench
- Assorted Allen wrench
- Chisels, punches
- Combination wrench set
- Crimpers
- Lineman's pliers
- Fuse pullers
- Grease gun, oil can
- Grinders / bonding equipment
- Hammer
- Lockout/Tagout materials
- Multimeter
- Needle nose pliers
- Penetrating oil
- Pocket knife
- Ruler – tape measure (must be non-conductive material)
- Screwdrivers, assorted including Phillips, straight-end
- Shunts
- Slip joint pliers (Channel Locks – brand)
- Switch gauge, filing gauge, obstruction gauge
- Terminal wrench
- Wire strippers

Often during inspection and maintenance, the signal maintainer performs mechanical and electrical tests. Each test requires a particular tool or set of tools. There are many specialized tools that will become part of a signal maintainer's regular duties. Some are shown in the next section.

# Module 7

## GUIDELINES AND RECOMMENDED PRACTICES

### Outline

- 7-1 Overview
- 7-2 Recommended Characteristics for Jumpers
- 7-3 Removing Signal Equipment from Service
- 7-4 Returning Signal Equipment to Service
- 7-5 Summary

### Purpose and Objectives

The purpose of this module is to provide the participant with a list of best practices and recommendations regarding characteristics for jumpers, removing equipment from service, returning equipment to service.

Following the completion of this course, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Discuss recommended characteristics for devices used in the removal of equipment from service
- Identify recommended procedures for removing equipment from service
- Identify recommended procedures for placing equipment back into service

### Key Terms

- Alligator Clips
- Dispatcher
- Eyelet
- Flag Person
- Hours Of Service
- Jumpers
- Jumper Bag
- Jumper Tags
- On Track Protection

## 7-1 OVERVIEW

Most railway systems have structured procedures in place for signal equipment to be taken out of service as well as for the equipment to be returned to service. These procedures may include informing the **dispatcher** (RTS authorized personnel) of information involving the equipment being removed from service up to and including critical information and details regarding malfunctioning signal equipment, especially at highway grade crossings. Other procedures may include the assignment of flag persons or police officers near highway grade crossings as well as attaining any on track safety protections necessary for the signal maintainer's work.

**Note: Signal maintainers must be aware of and follow all procedures set by their railroad transportation agency.**

This module, developed with a consortium of rail signal specialists with nearly 700 combined years of experience identifies some of the best practices the signal maintainer should take to remove equipment from service as well as to return equipment to service.

## 7-2 RECOMMENDED CHARACTERISTICS FOR JUMPERS

The use of jumpers is a common method of disabling signal equipment used in the signal industry. **Jumper wires** also known as *jumpers*, in the application of disabling signal equipment, are lengths of wire of a certain gauge used to connect points in a circuit which are separated or open due to a signal malfunction or for work which affects the proper operation of the signal system. For example, track equipment which intermittently shunts a track while working can cause a highway grade crossing warning system to activate when a train is not approaching. Jumpers are used to deactivate that portion of the warning system.



### Warning: Safety Precautions!

Any protection temporarily defeated by the use of a jumper must be provided by other means.

### Warning: Safety Procedures!



- The use of jumpers in signal circuits to disable the normal engineered operation of the signal system **is an extremely dangerous practice and should be avoided except in the most necessary of circumstances.**
- Jumpers may also be used to enable/activate equipment
- The signal maintainer must have a complete understanding of the consequences of disabling circuits.
- When jumpers are in use, an engineered system that ensures the safety of the public, agency employees, and equipment is bypassed.
- Signal maintainers who do not treat jumpers with the utmost care risk injury and death to all who are dependent on these signal safety systems to operate correctly and as designed.
- All Agency policies, procedures, protocols, and accounting for deactivated circuits **MUST** be strictly followed.
- Signal maintainers risk employer discipline, personal liability, and criminal prosecution for the misuse of jumpers.
- No unauthorized jumper shall be used.

#### Consequences of Improper Use of Jumpers

The unauthorized use of jumpers can have dire consequences on the safety of rail passengers and workers. In October 2012 an Amtrak train entered the Niles, Michigan yard from the main track traveling at 61 mph. The train derailed about 291 feet after diverging from the main track and traveled 1,148 additional feet before coming to a stop on a yard track. See *Figure 7.1*.

## GLOSSARY

**Active Highway Grade Crossing System :** A highway grade crossing system that includes visible, audible, and physical barriers, which are activated on the approach of a train.

**Alligator Clips:** A type of fixed termination for jumpers.

**Alternating Current Track Circuit:** A type of track circuit where an electric current that reverses its direction many times a second at regular intervals, also known as Power Frequency.

**Automatic Train Control:** a system that initiates a penalty brake application if the engineer fails to reduce speed in compliance with cab signal indications.

**Armature:** Related to relays, pivotal metal fixture that is linked to the heel contacts.

**Aspect:** the nature or appearance of a signal.

**Audio Frequency Track Circuit:** The AF track circuit uses a **transmitter** and a receiver. The transmitter introduces an audio signal of a specific assigned carrier frequency and modulation rate into the track either through wires connected directly to the rails. **Block:** area of track between two towers.

**Block system:** system of rules made for travel within and between blocks and communication between adjacent towers. The main rule was that only one train could be moving within a given block.

**Cantilever Flashing Light Signal:** Common apparatus used at a highway-rail grade crossing

**CFR 214:** Specific guidelines set into law by the federal government to protect roadway workers while they are on the job. Many railroad systems use CFR 214 as the foundation for developing their own recommendations and guidelines for roadway worker protection.

**Circuit Components:** Fuses, transformer, relays, and contacts

**Closed Circuit principle:** The principle of circuit design where a normally energized electric circuit which, on being interrupted or de-energized, will cause the controlled function to assume the most restrictive condition.

**Coded Track Circuit:** A type of track circuit which can be AC or DC circuit where the energy source is transmitted as pulses through the circuit and the receiver is designed to respond to the pulses.

**Coil:** A relay component which possesses electromagnetic characteristics which impact the operation of other relay components, such as the heel.