**Training Aid**

**S&TC-0-2: Instructor Notes**

**History & Evolution of Signal Systems**

**Slide 1** – History of railroad signaling is a story of innovation, technology, and an obsessive search for safety. This obsession began more than 150 years ago and continues unabated today. Over the years, signal engineers have used whatever technology was available to them the make America's railroads safer and more efficient. Safety and efficiency are the purposes for railroad signaling.

**Slide 2** – Learning Objectives

* Recognize the history and development of modern signal and train control system and how signal systems evolved as new technologies became available.
* Understand that while the technologies employed in railroad signaling have changed, the fundamental principles have remained the same by comparing and contrasting older technologies with the new.
* Recognize how 49 CFR 236.0 determine the railroads’ method of operation and operating speeds.

**Slide 3** – Caution: When in doubt, go to the book!

**Slide 4** – Information: The FRA Rules, Standards, and Instructions are considered to be the minimum standard allowed for the installation, inspection, maintenance, and repair of signal and train control systems, devices, and appliances. Each railroad may adopt more stringent standards. Refer to your railroad’s signal standard and instruction manual for further guidance.

**Slide 5** – Early Railroad Operations: Trains operated according to a strict timetable, that is cannot leave a station until an appointed time and until any other trains they were to meet at that station have arrived. Rarely used as a block system, as if one train is delayed, all trains it is scheduled to meet are delayed. This can quickly lead to all trains on the railway being affected.

**Slide 6** – Telegraph on early railroads.

**Slide 7** – First telegraphic train order: September 22, 1851, Superintendent Charles Minot issues the first telegraphic train order.

**Slide 8** – Popular on single track lines in North America up until the 1980s, Train Order operation was less a block system and more of a system of determining which trains would have the right of way when train movements would come into conflict. Trains would make use of a predetermined operating plan known as the timetable which made use of fixed passing locations often referred to as stations. Amendments to the operating plan would come from a train dispatcher in the form of train orders, transmitted to the trains via intermediaries known as agents or operators at train order stations.

**Slide 9** – The first signals employed on an American railroad were a system of flags used on the Newcastle and Frenchtown Turnpike and Rail Roadin the 1830s. The railroad then developed a more effective system consisting of wooden balls, painted red, white or black, and hoisted up or down a pole on a rope-and-pulley system. The initial use of these signals was merely to indicate the on-time status of trains, rather than to control train movements. The wooden balls were often configured with lanterns for nighttime use. Ball signals were first used to direct train movements in 1852, on the New York and New Haven Railroad.

**Slide 10** – In a manual block system the line is divided into sections called *blocks*. At each point of division *signalmen*, in communication by telegraph, were stationed at *block posts*, with fixed signals to control the trains. When a train wished to enter a block, the signalman at its entrance communicated with the signalman at the exit of the block. If they agreed that the block was clear of trains, the signalman at the exit prevented any train from entering at that end, while the signalman at the entrance admitted the train, protecting it with a signal behind it. When the train reached the other end of the block, the signalman there advised the signalman at the entrance that the train had left the block, which was clear. The concept of trains operating via signal indication, in conjunction with train orders, was born.

**Slide 11** – Manual Block System: A block signal system wherein the use of each block is governed by block signals controlled manually or by block-limit signals or both upon information by telephone or other means of communication.

**Slide 12** – Manual Block System: As a train approaches Station Bravo the Bravo Signalman communicates with the Alpha Station Signalman to ensure that the block is clear. The Alpha Station Signalman sets the Alpha Signal to “STOP”, then communicates to the Bravo Station Signalman that the block is clear. The Bravo Station Signalman then sets the Bravo Signal to “Clear.” Once the train enters the block the Bravo Signalman sets the Bravo Signal to “STOP.”

**Slide 13** – Interlocking Plant: The manual block signal system solved many of the safety problems related to operating trains between junctions, but problems still existed at junctions and crossings. American signal engineers looked to an English innovation to improve safety and efficiency at junctions. A London based company, Saxby and Farmer had invented the first interlocking machine.

**Slide 14** – Interlocking Plant: A minimal interlocking consists of signals, but usually includes additional appliances such as switches and derails, and may include crossings at grade and movable bridges. Some of the fundamental principles of interlocking include:

* + Signals may not be operated to permit conflicting train movements to take place at the same time.
	+ Switches and other appliances in the route must be properly 'set' (in position) before a signal may allow train movements to enter that route.
	+ Once a route is established and a train is given a signal to proceed over that route, all switches and other movable appliances in the route are locked in position until either
		- the train passes out of the portion of the route affected, or
		- the signal to proceed is withdrawn and sufficient time has passed to ensure that a train approaching that route has had opportunity to come to a stop before passing the signal.

**Slide 15** – Basic Track Circuit:

* The electric track circuit was invented Dr. William Robinson.
* Connected the train directly to the signal system.
* Began movement toward automatic operation of the signal system.

**Slide 16** – Basic Track Circuit: Each circuit detects a defined section of track, such as a block. These sections are separated by insulated joints, usually in both rails. To prevent one circuit from falsely powering another in the event of insulation failure, the electrical polarity is usually reversed from section to section. Circuits are powered at low voltages (1.5 to 12 V DC) to protect against line power failures. The relays and the power supply are attached to opposite ends of the section to prevent broken rails from electrically isolating part of the track from the circuit. A series resistor limits the current when the track circuit is short-circuited.

When a track circuit is in its normal state current flows from the battery to the relay, energizing its coils. This indicates to the signal system that the track circuit is unoccupied and that the rails are not broken, hence it is safe to proceed.

If the track circuit is occupied by a train the wheels will “shunt” the current away from the relay causing it to de-energize setting the signal to “Stop” indicating that the track is occupied and that it is unsafe to enter.

**Slide 17**- Basic Track Circuit definition: An electrical circuit of which the rails of the track form a part.

**Slide 18** – Automatic Block Signal System:

* Automatic signal systems utilizing the new electric track circuit and semaphore signals became widely popular.
* Used to supplement the Train Order system increasing safety and efficiency.

**Slide 19** – Automatic Block Signal System definition: A block signal system where the use of each block is governed by an automatic block signal, cab signal, or both. A roadway signal operated either automatically or manually at the entrance to a block.

**Slide 20** – Automatic Block Signal System: By installing a series of track circuits between station the signal system now has the capability of monitoring track occupancy in the entire block between stations. This arrangement makes the communications between stations automatic, thereby relieving the block operator or block signalman from manually operating the signals.

**Slide 21** – Automatic Block Signal System: The simplest form of an Automatic Block Signal System uses track circuits to detect track occupancy and to automatically set the opposing block signal to “Stop.”

**Slide 22** – Automatic Block Signal System: The manual block system provided safety for train movements between stations, but was very inefficient as it only allowed one train at a time to occupy the block. The signal engineers of the day were able to improve operational efficiency by adding intermediate signals between stations to govern movement over each track circuit for train movements in the same direction.

**Slide 23** – Automatic Block Signal System: The function of a basic Automatic Block Signal System (ABS) is to increase efficiency by allowing one train to follow another into and through a series of blocks between stations. ABS also provides limited protection from opposing trains, but the primary protection remains the train order.

**Slide 24** – An Absolute Permissive Block (APB) Signal System is a variation of ABS that features a “Tumble down” function for opposing train movements. When a train enters the block, not only does the opposing signal get set to “STOP”, but all the opposing signal to the next station get set to “STOP” also. This provides “absolute” protection from opposing trains while still permitting following trains to operate into the block.

**Slide 25** – By the mid-1920’s three technologies were merging to allow for a giant leap in railroad signaling and train operations. The well understood principles of block signaling and interlocking principles began to merge with the emerging science of electronic communications.

**Slide 26** – Traffic Control System: In 1927, the New York Central installed the first Traffic Control System (TCS). This system place a series of manually controlled interlocking plants within an automatic block territory. These manual interlocking plants were connected to a central office machine where a single dispatcher could control the entire territory. The signal system now became the method of train operations. General Railroad Signal Company installed this system and went on to market it a Centralized Traffic Control (CTC), but CTC is a Traffic control System.

**Slide 27** – Automatic Train Stop: Mechanical ATS was more popular on rapid transit systems and dedicated commuter rail than freight or long distance passenger lines due to a combination of the increased complexity found in mainline railroad operations, the risk of inadvertent activation by debris or other wayside appliances, and the danger of emergency brake applications at high speeds.

In 1910 the Pennsylvania and Long Island Rail Road installed a mechanical ATS system covering various lines to New York Penn Station using the trip value system which was designed to prevent inadvertent activations from debris.

**Slide 28** – Automatic Train Stop: The General Railway Signal corporation introduced its Intermittent Inductive Automatic Train Stop system in the 1920s which made use of Inductive loops in a "shoe" mounted outside of the running rails. This system was also of the acknowledgment type. If a train passed a restrictive signal and the operator took no action within 5 seconds the system would stop the train. This system was installed by several railroads and continues to see service today. In September 1920, the Interstate Commerce Commission issued Order Number 13,514 requiring 49 railroads to install ATS on at least one of their passenger division.

**Slide 29** – Automatic Cab Signals: The main purpose of a signal system is to enforce a safe separation between trains and to stop or slow trains in advance of a restrictive situation. The cab signal system is an improvement over the [wayside signal](https://en.wikipedia.org/wiki/Railway_signal) system, where visual signals beside or above the right-of-way govern the movement of trains, as it provides the train operator with a continuous reminder of the last wayside signal or a continuous indication of the state of the track ahead.

All cab signaling systems must have a continuous in-cab indication to inform the driver of track condition ahead; however, these fall into two main categories. **Intermittent** cab signals are updated at discrete points along the rail line and between these points the display will reflect information from the last update. **Continuous** cab signals receive a continuous flow of information about the state of the track ahead and can have the cab indication change at any time to reflect any updates. The majority of cab signaling systems, including those that use coded track circuits, are continuous.

**Slide 30** – Automatic Train Control: Automatic Train Control (ATC) systems in the United States are almost always integrated with existing continuous cab signal systems. The ATC comes from electronics in the locomotive that implement some form of speed control based on the inputs of the cab signaling system. If the train speed exceeds the maximum speed allowed for that portion of track, an over-speed alarm sounds in the cab. If the engineer fails to reduce speed and/or make a brake application to reduce speed a penalty brake application is made automatically.

Due to the more sensitive handling and control issues with North American freight trains, ATC is almost exclusively applied to passenger locomotives in both inter-city and commuter service with freight trains making use of cab signals without speed control. Some high-volume passenger railroads such as Amtrak, Metro North and the Long Island Rail Road require the use of speed control on freight trains that run on all or part of their systems.

**Slide 31** – 49 CFR 236.0: This rule requires that a block signal system complying with the RS&I or a manual block system complying with the provisions of this section be installed where passenger trains operate at 60 or more miles per hour or freight trains operate at 50 or more miles per hour. Further, an automatic train stop, train control, or cab signal system shall be installed where any train operates at 80 or more miles per hour.

 This section details how a manual block system shall operate and requires that it be permanently in effect, i.e., all trains must be operated by manual block system rules.

 A **manual block system** is a method of train operation by mandatory directives or voice rules, in non signaled territory (or against current of traffic), which authorizes movements between defined limits or blocks, and conforms with 236.0(c)(1),(2),(3),&(4).

 The individual operating rules of a railroad will determine if the method of operation conforms to a manual block system.

 Note that a methodology, such as the track warrant control rules of some carrier’s, which permit and establish yard limits within designated blocks; does not conform to the above manual block system, because trains are permitted to enter the main track within designated yard limit areas without direct authority or regard for block occupancy.

**Slide 32** – 49 CFR 236.0: (1) Prior to December 31, 2015, where any train is permitted to operate at a speed of 80 or more miles per hour, an automatic cab signal, automatic train stop, or automatic train control system complying with the provisions of this part shall be installed, unless an FRA approved PTC system meeting the requirements of this part for the subject speed and other operating conditions, is installed.

(2) On and after December 31, 2015, where any train is permitted to operate at a speed of 80 or more miles per hour, a PTC system complying with the provisions of subpart I shall be installed and operational, unless FRA approval to continue to operate with an automatic cab signal, automatic train stop, or automatic train control system complying with the provisions of this part has been justified to, and approved by, the Associate Administrator.

(3) Subpart H of this part sets forth requirements for voluntary installation of PTC systems, and subpart I of this part sets forth requirements for mandated installation of PTC systems, each under conditions specified in their respective subpart.

As you can see 49 CFR 236.0 ties the train speed to the minimum requirement of the method of train operation.

**Slide 33** – Early level crossings had a flagman in a nearby booth who would, on the approach of a train, wave a red flag or lantern to stop all traffic and clear the tracks. Manual or electrical closable gates that barricaded the roadway were later introduced, intended to be a complete barrier against intrusion of any road traffic onto the railway. In the early days of the railways much road traffic was horse drawn or included livestock, requiring a full barrier crossing the entire width of the road. When opened to allow road users to cross the tracks, the gates were swung across the width of the railway, preventing any pedestrians or animals getting onto the tracks. The first US patent for such crossing gates was awarded on 1867.

**Slide 34** – Soon after the advent of the automobile, speeds were increasing and the popularity of enclosed cars made the concept of "stop, look, and listen" at railroad crossings difficult. Fatalities at crossings were increasing. Though the idea of automatic grade crossing protection was not new, no one had invented a fail-safe, universally recognized system. In those days, many crossings were protected by a watchman who warned of an oncoming train by swinging a red lantern in a side-to-side arc, used universally in the U.S. to signify "stop". It was presumed that a mechanical device that mimicked that movement would catch the eye of approaching motorists and give an unmistakable warning.

**Slide 35** – Today’s systems are highly visible, utilizing diamond grade retro-reflective materials and multiple flashing lights to simulate the swinging of a lantern. They also use sophisticated control systems to ensure activation when necessary, but minimize the delay to the motorists.

**Slide 36** – Many of today’s signal systems still utilize shelf-mounted or plug-in relays. With proper care, inspection, testing, and maintenance these devices will provide many decades of service into the future.

**Slide 37** – As railroad signaling continues its evolution the skills needed to inspect, test, and maintain these systems are also changing. The systems are providing more information to aid in trouble-shooting and repairing the system is often as easy as changing a processor card. However, the basic functions of the system are less transparent.

**Slide 38** – TCS control machines have evolved, but their primary functions have remained the same.

1. Initiate requests to the field (i.e., move a switch position, clear a signal, etc.).
2. Receive indications from the field (i.e., actual switch position, signal status, train location, etc.).
3. Display indication for the dispatcher.

**Slide 39** – Today’s systems

**Slide 40** – The signals of the past gave the engineer information about the track ahead and indicated what speed the train should travel.

**Slide 41** – Today’s information displays give the engineer much more train handling information and will enforce restriction.

**Slide 42** – As you can see modern railroad signaling is a exciting and growing discipline. Signalmen are is constant search for new technologies and new method to achieve the same goal as their predecessors – the safe and efficient movement of trains.

**Slide 43** – Today it is more important than ever that the railroad hire and retain the finest signalmen possible. The signal discipline has evolved from dedicated flagmen work day and night in all types of weather, to pipe fitters and machinist assembling and maintaining intricate mechanical interlocking plants with hundreds of moving parts and thousands of feet of pipeline. With the advent of electricity, signalmen found another tool to use in search of safety. Signalmen with a vast understanding of electricity keep the railroads running for nearly a century before the next evolutionary change came to the industry. Having built the first computers back in the 1920s that stretch for miles along the railroad it was only natural that signalmen would embrace the microprocessor age.

**Slide 44** – As train control systems become more complex and many functions become transparent to inspecting, testing and maintaining personnel it becomes ever more critical that signalmen know and understand the fundamental principles around which the systems are designed. Regardless of the technology being used if a signalman know what the system is supposed to do and knows how to conduct performance tests on the system they will be successful.

**Slide 45** – **The Signalman Axiom:** “Remember, there are lives at stake in this business.”

**Slide 46** – Closing