U.S. Department of Transportation

Federal Railroad Administration

PTC Test Bed Siding Signal Upgrade at the Transportation Technology Center

Office of Research, Development
and Technology
Washington, DC 20590

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Final Report
May 2018

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13. ABSTRACT (Maximum 200 words) The Federal Railroad Administration (FRA) contracted Transportation Technology Corporation, Inc. (TTCI) to continue work performed from February 2013 through December 2014 to upgrade the infrastructure and testing capabilities of the Positive Train Control (PTC) Test Bed by converting the existing siding on the Railroad Test Track (RTT) to a signaled siding. The PTC Test Bed was developed at the Transportation Technology Center (TTC) in Pueblo, CO, where a facility for developing and testing PTC-related technologies and systems is provided for the rail industry. As part of this project, all the required system checks were performed, as well as structures and equipment being procured and installed.			
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

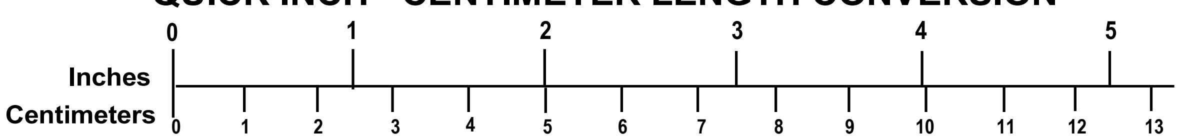
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

Contents

Illustrations

Executive Summary

The Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) to develop a Positive Train Control (PTC) Test Bed at the Transportation Technology Center (TTC) in Pueblo, CO. The PTC Test Bed is intended to provide an industry resource for testing PTC-related systems, equipment, and technologies in an environment free of certain constraints associated with revenue service test activities.

Upon the completion of the PTC Test Bed, TTCI continued to upgrade its infrastructure and testing capabilities at TTC. The scope of work for this project performed from February 2013 through December 2014 was to convert the existing siding on the Railroad Test Track (RTT) from non-signaled territory to a signaled siding that would support additional test scenarios. The project included updates to the control points on both ends of the siding, as well as the installation of an additional equipment house and signaling equipment on the siding.

System checks were performed to ensure correct functional operation due to the installation and testing of required structures and equipment.

1. Introduction

To assist the North American railroad industry with implementation of Positive Train Control (PTC), the Federal Railroad Administration (FRA) sponsored work performed by Transportation Technology Center, Inc. (TTCI) to develop a PTC Test Bed at the Transportation Technology Center (TTC) in Pueblo, CO, from February 2013 through December 2014. The PTC Test Bed was built to provide an industry resource for testing PTC-related systems, equipment, and technologies in an environment free of the challenges associated with revenue service test activities.

1.1 Background

As the Rail Safety Improvement Act of 2008 first mandated, each Class I railroad and each entity providing regularly scheduled intercity or commuter rail passenger transportation must implement an FRA-certified PTC system on: (1) its main line over which 5 million or more gross tons of annual traffic and poison- or toxic-by-inhalation hazardous materials are transported, and (2) its main line over which intercity or commuter rail passenger transportation is regularly provided.[1] By law, a PTC system must be designed to prevent train-to-train collisions, over-speed derailments, incursions into established work zones, and the movement of a train through a switch left in the wrong position.[2]

On October 29, 2015, the Positive Train Control Enforcement and Implementation Act of 2015 extended the original statutory deadline for implementing PTC systems from December 31, 2015, to December 31, 2018.[3]

Conducting PTC-related testing on revenue service routes can present significant challenges, including:

- Scheduling test activities around revenue service traffic
- Obeying all operating rules or obtaining waivers (frequently a lengthy process)
- Dealing with difficulties associated with conducting stress testing (i.e., degraded equipment or high-capacity performance testing)
- Experiencing operational challenges with obtaining repeatable results
- Changing vital equipment (requires lengthy verification and validation processes before retest is possible)
- Conducting tests that may present unsafe conditions in a revenue service environment

Among its many uses, the PTC Test Bed can be used for supporting development of PTC systems, conducting performance evaluations of PTC system components, as well as performing

[1] Rail Safety Improvement Act of 2008, Pub. L. No. 110-432, § 104(a), 122 Stat. 4848 (Oct. 16, 2008), as codified at Title 49 United States Code (U.S.C.) § 20157.

[2] *See, e.g.*, 49 U.S.C. § 20157(i)(5); Title 49 Code of Federal Regulations (CFR) § 236.1005.

[3] Pub. L. No. 114-73, 129 Stat. 568, 576–82 (Oct. 29, 2015), *amending* 49 U.S.C. § 20157. *See also* The Fixing America's Surface Transportation Act, Pub. L. No. 114-94, § 11315(d), 129 Stat. 1312, 1675 (Dec. 4, 2015).

interoperability and compliance testing. Interoperability refers to the ability of a controlling locomotive to communicate with and respond to the railroad's PTC system, including uninterrupted movements over property boundaries. The PTC system development included, proof of concept demonstrations, system development testing, simulations, and on-track (field) testing.

Other examples of potential PTC Test Bed uses, both past and current, include the following:

- Preliminary field trials and debugging of PTC systems, functions, and components
- Development and testing of improved PTC braking algorithms
- Evaluation of the impact of communications system performance and loading on PTC system performance
- Development and testing of PTC positive end of train determination systems
- Development and testing of PTC train location systems
- Over-the-air testing of PTC-related communications devices and capabilities
- Demonstration of the operation of PTC highway-rail grade crossing protection systems
- Certification/acceptance testing of PTC systems or components
- Interoperability/interchange testing of multiple PTC systems

Modifications to the PTC Test Bed have enabled it to support more generalized PTC testing, such as for interoperability, functionality verification, and performance/stress characterization.

1.1.1 PTC Test Bed Early History

From 1997 to 1998, the PTC Test Bed was developed and implemented when Harmon track signal circuits were installed on the Railroad Test Track (RTT) to provide 9-aspect cab signaling needed to support subsequent National Railroad Passenger Corporation (Amtrak) testing. Twelve 6,000-foot track signal blocks were created by installing insulated joints and alternating current (AC) impedance bonds between adjacent signal blocks. Harmon Electrified ElectroCode 4+ track signal electronics were installed in 12 instrument cases located around the RTT at the junction of each pair of adjacent blocks. This equipment provided rail integrity monitoring and track occupancy indications for each signal block, and it provided 9-aspect cab signaling information to support Amtrak testing. By 2005, TTCI had implemented several radio systems at the test bed to support PTC and related technologies, including Advanced Train Control System (ATCS) "Spec 200" radios, Wi-Fi, and Global Positioning System (GPS)-based vehicle tracking.

By 2009, TTCI had begun testing the Vital PTC (VPTC) system and had made the following additions to the PTC Test Bed:

- PTC communications (wayside, locomotives, and base station) using Meteorcomm 900-MHz radios
- RailComm computer-aided dispatch (CAD) system
- Lockheed Martin VPTC back office server (BOS)

- PTC test local area network (LAN) segregated from the TTCI business LAN
- Wayside equipment bungalow located near RTT switch (SW) 602B
- Special test equipment for creating and controlling PTC test conditions
- PTC subsystem simulators and emulators

Also in 2009, TTCI expanded the PTC Test Bed capabilities by adding a 4,000-foot siding, which enabled the testing of two trains meeting and passing each other in PTC-controlled single track territory. Installation of the siding included:

- 4,000 feet of siding track with a centerline offset 20 feet from the RTT centerline
- Remotely monitored and controlled powered switches at each end of the siding and at each end of the RTT and Transit Test Track (TTT) crossover
- Dwarf signal lights at each switch used as switch point indicator lights

1.1.2 Upgrades to Support Communication Testing

In September 2010, upgrades were included in an operational representation of a PTC test environment to support developmental field testing of the PTC 220-MHz radio being developed by the railroad industry, and for other PTC-related tests. The test bed was configured to accept PTC communications equipment when it became available.

These upgrades were implemented to provide an interoperable train control (ITC)-compliant PTC environment representative of freight PTC operations so that the railroad industry would have a test facility capable of supporting developmental field testing of the PTC 220 MHz radio. The communication system included base station, locomotive, wayside PTC 220 MHz radios, as well as a wayside messaging server at each wayside location. Additional equipment was installed at each wayside location to support Wi-Fi communication links.

Additionally, the PTC Test Bed was upgraded so that additional PTC testing configurations could be supported. The following features were added:

- Wabtec Train Management Dispatch System (TMDS®[4]) and CAD system
- Wabtec Interoperable Electronics Train Management System (I-ETMS®[5]) and BOS
- I-ETMS® onboard systems for two locomotives
- Six 12,000-foot (~ 2 ¼-mile) signal blocks with PTC-capable 4-aspect block signaling
- GE Transportation Systems and Global Signaling, LLC (GETS) Wayside Interface Units (WIUs) for signal block ITC-compliant communications
- Ansaldo STS Microlok II WIUs for switch ITC-compliant communications

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[4] TMDS® is a registered trademark of Wabtec Corporation

[5] I-ETMS® is a registered trademark of Wabtec Corporation

These modifications greatly enhanced the capabilities of the PTC Test Bed to support ITC-compliant field testing of PTC communications, especially for the capabilities needed to support field development testing of the Meteorcomm PTC 220 MHz radio.

1.1.3 Additional PTC Test Bed Upgrades

Additional upgrades were made to the PTC Test Bed between 2011 and 2013. These efforts included an operational simulation of a PTC test environment that supported more generalized testing than just PTC communications testing. The expanded test support capabilities included those needed to support interoperability, functionality verification, and performance/stress characterization of I-ETMS® and related PTC equipment. The major tasks performed were as follows:

- <u>Expanded the number of PTC-controlled signal blocks on the RTT from 6 to 12</u> by taking advantage of the 12 broken rail detection blocks already in place, while retaining the capability to reconfigure to the previous 6 signal block configuration
- <u>Increased the number of powered and remote controlled/monitored switches on the RTT by two</u> by converting manual switches on the RTT to remotely monitored and controlled electrically powered switches (SW 301 and SW 304)
- <u>Updated each end of the siding to be control point locations</u> with the north end of the siding having two switches (SW 304 and 305) within the control point and signals at the clearance points of the switches on the RTT, Train Dynamics Track (TDT), and siding. The south end of the siding has four switches (SW 301, 302, 602A, and 602B) within the control point and signals at the clearance points of the switches on the RTT, TTT, balloon loop, and siding
    - Installed fiber optic communications to control point locations
    - Installed track signaling equipment, signal masts, signal heads, PTC WIUs and WMSs, and PTC 220 MHz radios
- <u>Installed PTC 220MHz radios</u> at the 10 intermediate signal locations
- <u>Upgraded speed protection capability</u> from 120 to 160 mph

1.2 Objective

The objective of this project was carried out between February 2013 and December 2014, to upgrade the PTC Test Bed infrastructure and testing capabilities by converting the existing siding on the RTT from dark territory to a signaled siding. The intent of the project was to enhance the PTC Test Bed to provide a dedicated PTC test environment to railroads and suppliers that represents what is found in revenue service, as well as to allow for additional test capabilities.

1.3 Overall Approach

The overall approach to the PTC Test Bed upgrade included completing the following major tasks:

- Procuring and installing the equipment required to make the siding a signaled siding, including:
  - Installing Signal House 303 near R73
  - Installing the necessary PTC equipment in Instrument Case 12, Signal Houses 100, 305, 303, 302, 602 and 201
  - Installing the required Signal House 303 clockwise and counterclockwise signals
  - Adding aspects to existing signals and updating application code for signaling system to reflect the status of the newly signaled siding
  - Replacing the hand-thrown switch in the middle of the siding to a powered switch, and adding equipment to signal, control, and monitor the switch from the control points
  - Updating the BOS and CAD system to reflect the changes made to the test bed (this task was performed under a separate FRA project)[6]
- Conducting on-track testing and demonstrating the fully functional signaled siding

1.4 Scope

The scope of this project included the following:

- Adding additional aspects to signals entering the siding on the RTT
- Adding additional signal masts at SW 303 in the middle of the siding for yard track entry onto the siding
- Upgrading SW 303 from a hand operated switch to a powered switch machine
- Installing a control point location at SW 303
- Upgrading existing equipment at the PTC switch control points (interlockings)
- Providing operational readiness and upgrades for the PTC Test Bed related equipment, wayside bungalows, and RTT signaling infrastructure

Figure 1 shows the RTT as a reference for the RTT locations described throughout this report.

[6] Federal Railroad Administration. (2018, May 7). "PTC Test Bed Back Office System and Computer-Aided Dispatch Upgrades." Technical Report, DOT/FRA/ORD-18/14. Available at: https://www.fra.dot.gov/eLib/details/L19502#p2_z5_gD.

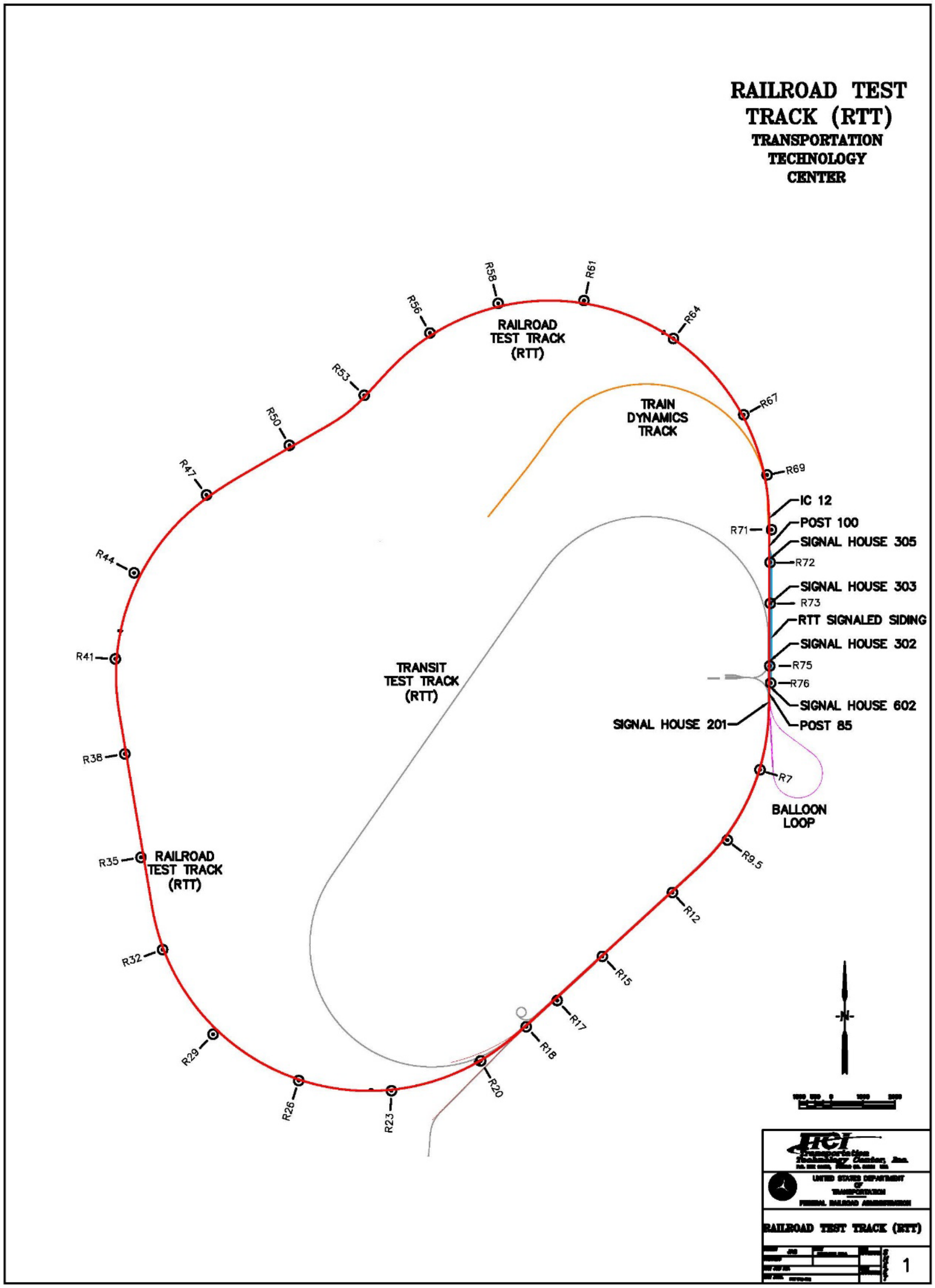

Figure 1. RTT Locations

1.5 Organization of the Report

This report is organized in four major sections. Section 1 is the introduction, which includes the background and history of the PTC Test Bed. Section 2 describes the details of the PTC Test Bed upgrades. Section 3 provides a short conclusion. Appendix A provides a summary of upgrades conducted to the PTC Test Bed equipment.

2. Summary Of Work

The following sections describe the specific work that was done to upgrade the PTC Test Bed.

2.1 Engineering Design

TTCI executed the engineering design and installation to add signaling to the existing siding on the RTT to enhance the capabilities of the PTC Test Bed at TTC. The conversion of the RTT siding included adding additional aspects to signals entering the siding on the RTT; adding additional signal masts at SW 303 in the middle of the siding for yard track entry onto the siding; upgrading SW 303 from a hand operated switch to a powered switch machine; installing a control point location at SW 303; upgrading existing equipment at the PTC switch control points (interlockings); and providing operational readiness and upgrades for the PTC Test Bed related equipment, wayside bungalows, and RTT signaling infrastructure.

2.2 Design and Layout

A new control point was installed near R73, which is located in the middle of the RTT siding. This included the installation of a new Signal House 303, new signaling equipment, powered switch machine, as well as signal masts and railroad signals. Figure 2 shows the RTT siding design. Equipment racks and GETS signaling equipment for block communications and control of the new signal aspects were designed, purchased, and installed. Figure 3 shows the installation of the signal masts that support yellow and red signal aspects to cover both clockwise and counterclockwise travel. Figure 4 shows the installation of the electronic controlled and remotely monitored switch. Following installation, TTCI conducted a system check of the equipment to ensure that it functioned as designed.

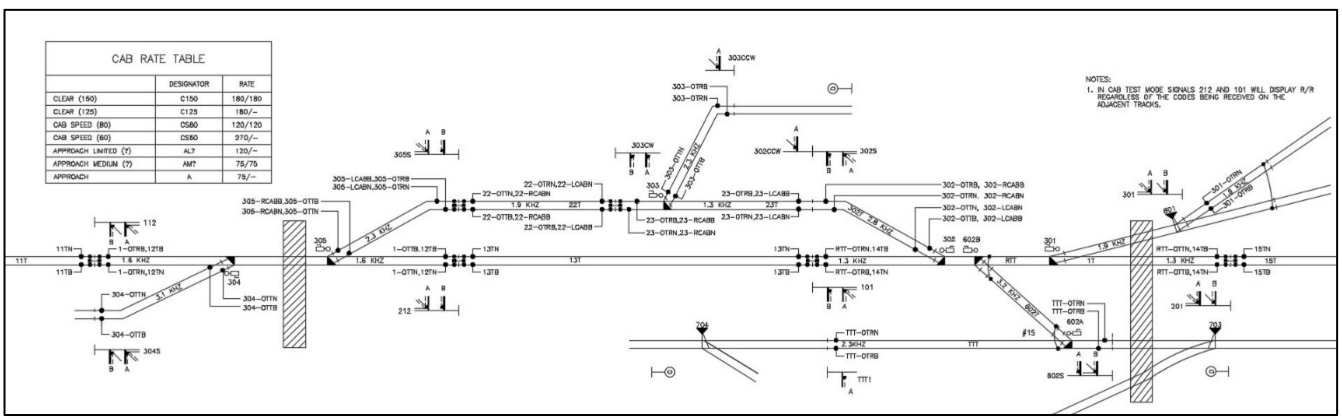

Figure 2. RTT Siding Design

Figure 3. 303 CCW and CW Signal Aspect Installation at R73

Figure 4. Electronic Controlled and Remotely Monitored SW 303

2.3 Block Signaling

The RTT is equipped for operations with either a 4-aspect wayside block signaling system or a 9-aspect cab signaling system, depending on the test requirements. As part of the signaling system, there are nine 6,000-foot blocks, one 8,000-foot block, and one 9,000-foot block that provide broken rail and track occupancy detection. As part of this project, TTCI added a 4,000-foot signaled siding to this block signaling system. The 4-aspect wayside signal system is capable of displaying a green, yellow, flashing yellow, or red aspect. A PTC electronics kit with an integrated ITC-compliant WIU is located at the track signal circuit electronic equipment case associated with each block, along with signal control equipment from GETS controlling the block signal lights.

The block signaling system was designed to allow trains that are traveling in the same direction to follow each other without risk of collisions. The block signaling system can detect if a particular block(s) is occupied, if a switch is misaligned within the block, or if there is a broken rail. Between each block signal, a low voltage current is transmitted through the rails and determines whether the track is open, closed, or shorted (i.e., shunted). When a track is occupied, shorting or shunting of a track occurs when the low voltage current travels from one rail to the other through the train's wheels and axles, which shorts the circuit. The system detects the short circuit and displays a restricted or stop signal on the opposing signals on each side of the occupied block. The circuit will likewise open in the event of a broken rail, which will also display a restricted or stop signal on the opposing signals on each side of the block.

2.4 Equipment

TTCI installed two pre-wired racks of signaling equipment provided by GETS: one rack was placed within Signal House 303 near R73, and the other rack was placed within Signal House 302 near R75. Additional signaling equipment was added to existing signaling equipment racks at Signal House 100, Signal House 305, and Signal House 602. A brief description of the main components is provided below.

2.4.1 ElectroLogIXS/EC5

The signal equipment previously installed on the RTT at intermediate signal locations is Electro Code 4-Plus (EC4-Plus), which is compatible with the new ElectroLogIXS/EC5 equipment installed in Signal House 303. Figure 5 shows the ElectroLogIXS/EC5 equipment, as installed in Signal House 303. The ElectroLogIXS/EC5 is capable of ground fault detection; train detection; broken rail detection; light out protection; approach lighting control; alternating current (AC) power off detection; cab signal output control; track switch controller protection (with vital two-wire inputs); and release of electric locked switches (with relay drives controlling approach indication of signals). The ElectroLogIXS/EC5 sends and receives coded pulses through the track at each end of the block. Direct current (DC) track circuits are used to input and export code pulses on and off the track. To detect trains, the tracks are used as conductors. The ElectroLogIXS/EC5 devices placed at both ends of the control block use the coded pulses to communicate with each other and synchronize the systems to alternately send and receive data in both directions. The hardware protection and software detection schemes are used to enhance the reliability of the communications and system signaling.

Wayside signaling is accomplished through sequential control and illumination of the wayside signal aspects. Information that is received within the ElectroLogIXS/EC5 consists of coded signals from the track circuits, inputs from relay contacts, or other solid-state devices with digital outputs. Reliable inputs are read and processed by several microprocessors in a logical manner that provides reliable control outputs.

Figure 5. ElectroLogIXS/EC5

2.4.2 Audio Frequency Train Activated Circuit—Model II

The Audio Frequency Train Activated Circuit Model II (AFTAC II) is an FM audio overlay system. The AFTAC II was designed to be used with systems that control crossing warning devices at highway-rail grade crossing locations and in train control systems when overlay train detection is needed. For the purpose of the PTC Test Bed, the AFTAC II is used for train detection on the RTT siding as well as train detection for the turnout for SW 303, located in the middle of the siding. Figure 6 shows the AFTAC II housing installed in Signal Houses 302, 303, and 305.

Figure 6. AFTAC II

2.4.3 Switch Controller

The switch controller combines a vital switch control relay with a non-vital solid state control and overload electronics. Figure 7 shows the switch controller installed at Signal House 303 that controls SW 303.

Figure 7. Switch Controller

2.4.4 Cab Signal Generator and Filter Coupler

The Cab Signal Generator (Electro Cab 101) is a high energy 100 Hz square wave inverter that can be coded. The high impedance allows the use of a coding relay contact or a solid-state code generator that will key the Electro Cab 101 output. The keying circuit design, within the Electro Cab 101, turns the component on or off at the rising or reducing edge of the 100 Hz signal, which can decrease excess noise caused by coding. A 50 percent duty cycle is guaranteed by an integrated circuit oscillator network that improves reliability and efficiency and limits output noise generation.

The Filter Coupler (FC-101) filter coupler is a series resonant device that passes the sine wave components of the 100 Hz square wave produced by the Electro Cab 101. The FC-101 filter does not convert the entire cab generator output to an actual sine wave, however, it does filter enough of the generator's output to allow the Electro Code 101 to operate consistently. The combination of the Electro Cab 101 and FC-101 are used at Signal Houses 100, 302, 303, 305, and 602 to provide cab signaling on the RTT siding and the three turnouts located on the RTT siding. Figure 8 shows the Electro Code 101 and FC-101 filter coupler installed in these signaling houses.

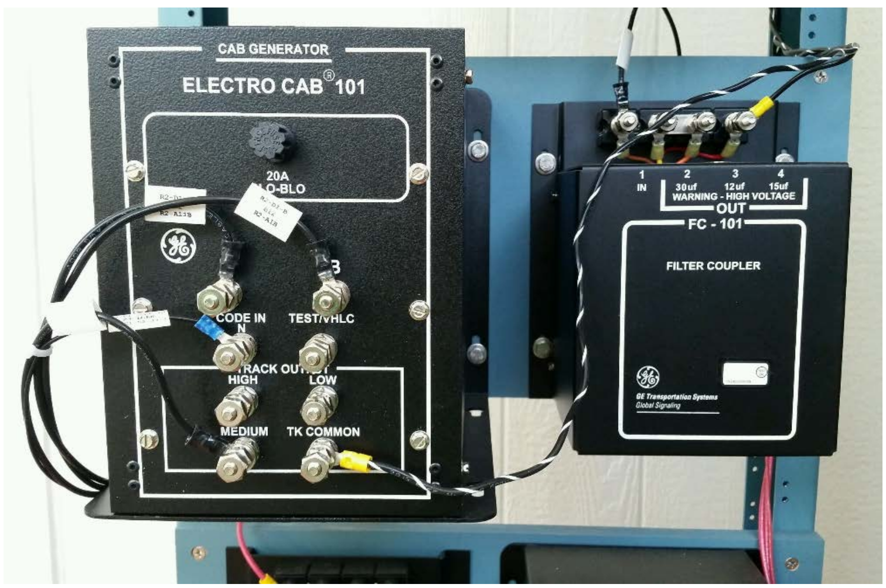

Figure 8. Electro Cab 101 Cab Generator and FC-101 Filter Coupler

2.5 Testing

A combination of system-level and component-level checkout testing was conducted to verify proper installation of the new equipment on the PTC Test Bed. The existing RTT signal system software was updated to integrate the changes implemented on the RTT siding into the logic. Track Input Simulator (TIS) boxes were designed to transmit and receive E-Code and Electrocode track circuit signals, and were temporarily used to test all the track signals and the logic. During testing, TIS boxes were used to simulate 4-aspect track codes, and to verify that the aspect associated with each signal code was correct. TTCI and GETS also verified that the signal aspects, track codes, and cab rates were working in the clockwise and counterclockwise directions. The system checks verified that the equipment was installed and functioning per the design.

3. Conclusion

FRA contracted TTCI to upgrade the PTC Test Bed at TTC. This task was performed by converting the existing siding on the RTT from dark (non-signaled) territory to a signaled siding that would enhance the operational scenarios that can be supported during testing of PTC-related systems, components, and equipment. TTCI acquired and installed the necessary components, including signal masts, signal lights, and wayside components in Instrument Case 12, and Signal Houses 100, 305, 303, 302, 602, and 201. System and component level testing was conducted to verify proper installation of equipment on the PTC Test Bed. TTCI, with the support of GETS, demonstrated that the signaled siding functioned according to the GETS signal aspect charts, which effectively met the requirements of this project.

Appendix A.
Summary of Equipment Upgrades

- Instrument Case 12
  - Signal aspects
  - Miscellaneous installation hardware
- Signal House 100
  - Signal aspects
  - ElectroLogIXS/EC5 Slot 2 Hardware
  - CAB 101 (305-RCAB)
  - FC-101 (305-RCAB)
  - Cabling and miscellaneous installation hardware
- Signal House 305
  - Signal aspects
  - ElectroLogIXS/EC5 Slot 4 Hardware
  - AFTAC II (23-OT)
  - CAB 101 (23-RCAB and 305-LCAB)
  - FC-101 (23-RCAB and 305-LCAB)
  - Cabling and miscellaneous installation hardware
- Signal House 303
  - Equipment housing
  - Power sources
  - Two signal masts/foundations/signal aspects
  - ElectroLogIXS/EC5
  - Electrified Electro Code Interface
  - AFTAC II (23-OT/22-OT and 303-OT)
  - Switch Controller
  - CAB 101 (23-LCAB and 22-RCAB)
  - FC-101 (23-LCAB and 22-RCAB)
  - Surge arrestors, cabling, miscellaneous installation hardware
  - Installation of electronic controlled and remotely monitored switch
- Signal House 302
  - Signal aspects

- ElectroLogIXS/EC5 Slot 4 Hardware
  - Electrified Electro Code Interface
  - AFTAC II (22-OT)
  - CAB 101 (22-LCAB and 302-RCAB)
  - FC-101 (22-LCAB and 302-RCAB)
  - Cabling and miscellaneous installation hardware
- Signal House 602
  - CAB 101 (302-LCAB)
  - FC-101 (302-LCAB)
  - Cabling and miscellaneous installation hardware
- Signal House 201
  - Signal aspects

Cabling and miscellaneous installation hardware

Abbreviations and Acronyms

AC	Alternating Current
AFTAC	Audio Frequency Train Activated Circuit
Amtrak	National Railroad Passenger Corporation
BOS	Back Office Server
Electro Cab 101	Cab Signal Generator
CAD	Computer-Aided Dispatch
DC	Direct Current
FRA	Federal Railroad Administration
FC-101	Filter Coupler
GETS	GE Transportation Systems and Global Signaling, LLC
GPS	Global Positioning System
I-ETMS®	Interoperable Electronic Train Management System
ITC	Interoperable Train Control
LAN	Local Area Network
PTC	Positive Train Control
RTT	Railroad Test Track
SW	Switch
TDT	Train Dynamics Track
TIS	Track Input Simulator
TMDS®	Train Management Dispatch System
TTC	Transportation Technology Center (the site)
TTCI	Transportation Technology Center, Inc. (the company)
TTT	Transit Test Track
VPTC	Vital Positive Train Control
WIU	Wayside Interface Unit