U.S. Department of Transportation
Federal Railroad Administration

Track Inspection Time Study*

* Required by Section 403 of the Rail Safety Improvement Act of 2008 (Public Law 110-432, Div. A.)

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

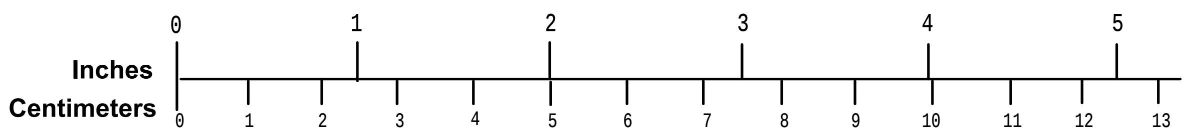
VOLUME (APPROXIMATE)

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)

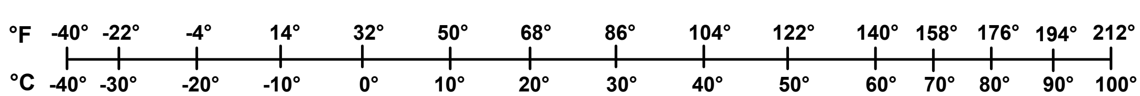
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



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

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Acronyms

ATIP	Automated Track Inspection Program
BMWED	Brotherhood of Maintenance of Way Employes Division
C3RS	Confidential Close Call Reporting System
CFR	Code of Federal Regulations
CWR	Continuous Welded Rail
DOT	U.S. Department of Transportation
FRA	Federal Railroad Administration
GPR	Ground Penetrating Radar
GRMS	Gage Restraint Measurement System
LIDAR	Light Detection and Ranging
MPH	Miles Per Hour
NIP	National Inspection Plan
NTSB	National Transportation Safety Board
NPRM	Notice of Proposed Rulemaking
PDF	Probability Density Function
POD	Probability of Detection
RITF	Rail Integrity Task Force
ROC	Receiver Operating Characteristic
RSA	Rail Seat Abrasion
RSAC	Railroad Safety Advisory Committee
RSIA	Rail Safety Improvement Act of 2008
RWP	Roadway Worker Protection
TGMS	Track Geometry Measurement System
TSS	Track Safety Standards
VTI	Vehicle-Track Interaction

Executive Summary

BACKGROUND

Section 403 of the Rail Safety Improvement Act of 2008 (RSIA) requires the Secretary of Transportation to conduct a study of the track inspection process. Specifically, Section 403 calls for the Secretary to conduct a study to determine whether the required intervals of track inspections for each class of track should be amended; whether track remedial action requirements should be amended; whether different track inspection and repair priorities or methods should be required; and whether the speed at which railroad track inspection vehicles operate and the scope of the territory they generally cover allow for proper inspection of the track, and whether such speed and appropriate scope should be regulated by the Secretary.

This report describes a study conducted by the Federal Railroad Administration (FRA), on behalf of the Secretary, in response to the requirement in Section 403 of the RSIA. The FRA Office of Railroad Safety prepared this report with assistance from FRA's Office of Railroad Policy and Development and the Volpe National Transportation Systems Center. FRA's Office of Railroad Safety is responsible for promoting and regulating safety nationwide throughout the railroad industry. The Office of Railroad Safety formulates and issues regulations under Title 49 Code of Federal Regulations (CFR). These regulations specify minimum safety requirements for track, equipment, communications systems, and other aspects of the railroad industry and infrastructure.

The current report focuses on aspects of track inspection. Regulations pertaining specifically to track safety are found at 49 CFR Part 213, commonly referred to as the Track Safety Standards (TSS). The TSS define nine different classes of track, with Class 9 being the highest quality track and Class 1 being the lowest. For each class of track, the TSS prescribe various standards for track components, including ties, rail, fastening systems, and ballast. The TSS also prescribe inspection intervals for each class of track. All classes of track must be visually inspected by an authorized track inspector either on foot or in a hi-rail vehicle. In addition to visual inspections, the TSS also prescribe the use of several automated inspection systems; the number, type, and frequency of different automated inspections depend on the class of track.

STUDY METHODS

In order to successfully fulfill this Congressional mandate, FRA believed it was necessary to obtain a "snapshot" of the current track inspection process. A survey of a random sample of actively working track inspectors, as well as interviews with labor union officials and various levels of railroad management, provided the necessary information.

FRA also compiled data related to track defects identified by FRA track inspectors over a 4-year period (2006–2009). These data provide an indication of the most prevalent defects as well as those that industry track inspectors fail to identify. In addition to the collection of survey data, interview data, and FRA track defect data, an "ideal observer" model was constructed for visual track inspection. The ideal observer model provides a theoretical upper limit, based on previously compiled empirical data, on how well the best possible observer can perform. The primary purpose of the "ideal observer" model is to have a baseline against which current inspection speeds reported in the survey can be compared.

RESULTS

Survey data indicates that nearly all railroad track inspectors are initially trained through on-the-job training, but half also have formal classroom training. The vast majority of track inspectors (85 percent) work 8-hour days and 10 percent reported working 10-hour days. Survey results indicate that track inspectors frequently work beyond the scheduled workday. Over half indicated that in the month prior to the survey, they had worked—on a rest day—an average of three times.

The inspector's job involves inspecting track either from a hi-rail vehicle or on foot. On average, inspectors spend 5 hours per day doing inspections. The remainder of their day is devoted to job briefings, waiting for track time, travel, and reporting inspection results. Survey respondents' territory size averaged slightly less than 80 miles. The reported number of miles inspected per day varies depending upon the extent to which the hi-rail vehicle is used, the number of curves on the track, and whether the track is jointed or continuous welded rail (CWR). The reported hi-rail speed varied from 5 mph to 30 mph, depending on the type and condition of the track being inspected. The ideal observer analysis generally suggested that speeds reported by track inspectors through the survey are adequate.

The survey asked respondents to indicate how they typically identify various track defects. Nearly 10 percent rated two conditions as not readily detectable: rail seat abrasion and torch-cut or burned-bolt hole in rail. About a third of respondents indicated that they use track geometry measurement systems (TGMS) to aid them in identifying areas with track geometry related defects.

Inspector comments on non-inspection duties were the most prevalent, and reflected that such tasks often take time away from their primary track inspection duties. Inspectors also commented about difficulties getting adequate track time for conducting inspections.

Interviews with labor union officials emphasized the need for standardized training. Union officials also reported that there is pressure to do more work in less time. Both union officials and railroad management indicated that, given adequate time, visual inspection can find most of the track safety issues but automated systems are an essential tool for guiding and focusing the visual inspection process.

Review of FRA track defect data revealed that defects related to turnouts, rail joints, crossties, and switches/frogs were, respectively, those most commonly found by FRA track inspectors and therefore those most likely missed by the railroad track inspector.

RECOMMENDATIONS

The data collected and analyses conducted indicate that improvements in the current track inspection process require further investigation of the following issues:

- Expanded use of automated inspection systems to supplement visual inspections.
- Standardization of track inspector training.
- Maximum speed of track inspections being conducted from a hi-rail vehicle.
- Alleviation of oftentimes punitive railroad operating practices and culture with respect to the track inspection process.

Expanded use of automated inspection systems, beyond those currently prescribed in the TSS, will help alleviate the problem of missed defects that could cause derailments. Increased use of automated inspection systems would provide the opportunity for inspectors to conduct more thorough visual inspections at problem areas identified by the automated inspection systems thus helping to prevent a defect from causing a derailment. Track inspectors performing visual inspections cannot readily or easily detect certain track defects; according to the survey, torch cut bolt holes and rail seat abrasion (RSA) of concrete ties are on the top of the list. Torch cutting is now a prohibited practice, and various automated systems are available or in the design stages to detect RSA.

Both the interviews with labor union officials and the survey data identified standardization of training as an issue. The FRA is aware of the general non-uniformity in training practices and will consider establishing formal guidelines and a skeleton curriculum that will establish minimum training requirements.

There is no general, industry-standard operating speed for hi-rail vehicles used in track inspection. Sections 213.233(b) and 213.365(b) of Title 49 CFR do provide that if a vehicle is used for visual inspection, the speed of the vehicle may not be more than 5 mph when passing over track crossings and turnouts; otherwise, the inspection vehicle speed shall be at the sole discretion of the inspector, based on track conditions and inspection requirements. While labor union officials contend that 20 mph is reasonable as a general standard, this may not be appropriate for certain track conditions necessitating detailed inspections. FRA would prefer to focus more on ways to achieve efficient and effective inspections rather than on establishing a general, maximum inspection speed. Using various models such as the ideal observer and the collection of empirical data will provide information to evaluate if the current speeds, as reported by track inspectors, are sufficient to detect common defects visually.

Survey and interview participants expressed concerns about railroad operating practices and safety culture. Pressure to complete work, dispatcher decisions, and inadequate track time are factors that can be alleviated by changes in railroads' operating practices. Also non-inspection duties assigned to track inspectors limit the time they have available for track inspections. Implementation of a safety reporting system is one means to address these issues and to begin to change the safety culture in the maintenance-of-way departments. This approach would provide a confidential, non-punitive, and anonymous way for employees to report near-misses and other safety risks, such as management pressure to either ignore or downplay the severity of identified track defects.

The FRA will research solutions to these issues and present the results to the Railroad Safety Advisory Committee (RSAC) for formal consideration. The RSAC provides a continuing forum for advice and recommendations to FRA on rulemakings and other safety-related program issues, enabling FRA to carry out its regulatory responsibilities for railroad safety more effectively. The RSAC includes representation from all of the agency's major stakeholder groups: both large and small passenger and freight railroads, labor organizations, States, suppliers and manufacturers, and other interested parties, such as the National Transportation Safety Board (NTSB). The RSAC allows these groups to work cooperatively in developing the best solutions to safety issues, including identifying regulatory options to implement solutions where regulation appears necessary. The RSAC process will result in recommendations on whether updates to current FRA safety regulations are necessary for the issues raised in Section 403 of RSIA.

1. Introduction

Section 403 of the Rail Safety Improvement Act of 2008 (RSIA), formally Public Law 110-432, Div. A., requires the Secretary of Transportation to conduct a Track Inspection Time Study. Appendix A contains a complete copy of Section 403 of the RSIA. The study is to determine whether the required intervals of track inspections for each class of track should be amended; whether track remedial action requirements should be amended; whether different track inspection and repair priorities or methods should be required; and whether the speed at which railroad track inspection vehicles operate and the scope of the territory they cover allow for proper inspection of the track.

The Federal Railroad Administration (FRA) believes that the intent of Section 403 of the RSIA is to address the overall effectiveness of the track inspection process as it currently exists, and to investigate ways to improve the process. To address the requirements of Section 403 of the RSIA, FRA—on behalf of the Secretary and through a neutral, third-party contractor—conducted a survey of railroad industry track inspectors, as well as interviews with various levels of railroad and union management. The purpose of FRA's survey-and-interview approach was to obtain a "snapshot" of the current state of the track inspection process. This was necessary in order to gain information about the duties of railroad track inspectors and the characteristics of the territory for which they are responsible. In addition, an understanding of the overall effectiveness of the current inspection process, and which aspects of the process could be improved, was sought. Furthermore, to address additional requirements of Section 403 of the RSIA, FRA has been participating in the Railroad Safety Advisory Committee's (RSAC) Rail Integrity Task Force (RITF) of the Track Safety Standards Working Group, along with industry representatives. Recommendations concerning new regulations for rail integrity remedial actions, as well as the frequency of inspections for internal rail flaws, are being developed in the RITF.

Currently, Title 49 Code of Federal Regulations (CFR) Part 213, Track Safety Standards (TSS), contains requirements that FRA believes necessary to maintain safe track and a stable, viable rail network. These standards are *minimum* safety standards. The TSS define nine classes of track, Class 1 being the lowest quality track and Class 9 being the highest. The TSS also prescribe the maximum operating speed for freight and passenger operations for each class of track. In addition, the TSS permit a track classification below Class 1; this track is called "excepted track" over which limited operations are allowed under special conditions. The TSS define discrete allowable limits for certain track characteristics. These limits comprise threshold levels that depend on the class of track. Generally, more stringent (restrictive) limits are imposed for higher track classes. When threshold levels are exceeded, the track has an FRA track "defect." When a railroad learns that it is not in compliance with the TSS (for example, when a track defect exists), it must:

- Remediate the defective condition such that the track is now in compliance with the TSS;
- Reduce maximum train speed, thereby temporarily lowering the class of track to one for which the track condition does not exceed the allowable limits; or
- Remove the track from service.

The TSS are broken down into Subparts A–G, as shown in Table 1. Subparts A–F generally address track classes 1–5. Specifically, Subpart A addresses general issues such as prescribing maximum track speeds for Classes 1–5, as well as designation of qualified personnel, penalties, and waivers. Subparts B–D address requirements for various components of the track structure, track substructure support, and surrounding wayside area. Subpart E is smaller in scope and addresses the application of derail devices. Subpart F addresses inspection requirements, including frequency of inspection and inspection recordkeeping. Specifically, Subpart F addresses the requirements for inspection of rail for internal defects as well as other automated inspection techniques. Subpart G generally combines all of the subjects addressed in Subparts A–F and modifies each for application to Track 6–9. Subpart G is often referred to as the "high-speed standards."

Table 1. Subparts of Track Safety Standards

Subpart	Title	Track Classes
A	General	1–5 and 6–9[1]
B	Roadbed	1–5
C	Track Geometry	1–5
D	Track Structure	1–5
E	Track Appliances and Track-Related Devices	1–5
F	Inspection	1–5
G	Train Operations at Track Classes 6 and Higher	6–9

In addition to FRA track component requirements contained in Subparts B–D for track classes 1–5 and portions of Subpart G for track classes 6–9, many railroads have internal standards for various track integrity parameters, including track geometry, sizing of internal rail defects, and visual assessment of track components. These internal standards are often more stringent than the TSS. Railroads generally deem these internal standards necessary, as they recognize that the FRA standards are minimum safety standards. Many railroads' internal standards are implemented using a two-level strategy. The first level is a maintenance threshold. This threshold is more restrictive than the FRA standards. A second-level threshold, which is often referred to as a safety level threshold, is more critical than a maintenance level threshold. Internally, a railroad may set its safety level threshold at the FRA minimum safety standard level or slightly more stringent than the FRA minimum safety standard, depending on the preferences and operating practices of the particular railroad.

In order to maintain a safe rail network, the TSS specifically prescribe several mandatory inspection techniques and procedures, including routine visual track inspections.[2] The TSS also address threshold safety levels for several automated inspection systems, including internal rail flaw, track geometry, and gage[3] restraint measurement systems (GRMS).

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[1] 49 CFR Sections 213.2, 213.3, and 213.15 directly apply to Classes 6–9, as well.
[2] Throughout this document, the term "visual inspection" will refer to an inspection performed by a human. This is not to be confused with "machine-vision inspection," which refers to an automated inspection using machine-vision technologies.
[3] "Gage" refers to the lateral distance between the two rails comprising a section of track.

This report will use the FRA TSS as a baseline for evaluating the results from the survey. In addition, the report will briefly address potential changes to the TSS in order to improve the effectiveness of the visual and automated aspects of the track inspection process.

2. Track Inspection Background and Methodology

2.1 Defective Track Conditions Addressed in the Track Safety Standards

The goal of the inspection process is to prevent incipient failure of the railroad track and the resulting derailment potential of a rail vehicle. The current standards for the various track components in the TSS are divided into three primary sections for track classes 1–5: roadbed (Subpart B), track geometry (Subpart C), and track structure (Subpart D). Portions of Subpart G address similar requirements for track classes 6–9. Subpart B prescribes standards for the roadbed. This section briefly addresses the issues of water drainage and excessive vegetation. Excessive vegetation presents a fire hazard and can obstruct the visibility of railroad signs and signals. Standing water can result in a softened roadbed that does not provide sufficient support for the track structure, including the rails, ties, and ballast. Subpart C prescribes standards for track geometry parameters, including track gage and cross-level, as well as vertical and lateral deviations of each rail. These components include ballast, crossties, rails, rail joints, anchors, and fasteners. Finally, Subpart D prescribes the standards for each of the critical components that comprise the track structure. The roadbed and track structure sections primarily address issues that can be evaluated visually. Track geometry is one measure of the overall condition of the track structure. Degraded track geometry may be the result of defective conditions that can be detected visually, such as those addressed in the roadbed and track structure sections. However, degraded track geometry can also result from conditions that are not visible on the surface. For example, internally rotted wooden ties, abrasion on the bottom surface of concrete ties, or poor subgrade conditions may not be initially detectable by visible means, but if these conditions exist in excess, then degraded track geometry will result when the track is loaded by a rail vehicle. Track geometry, therefore, can be thought of as a means for quantifying the overall condition of the track structure and substructure.

2.2 Prescriptive vs. Performance-Based Thresholds

In any field where safety is an issue, different inspection philosophies and approaches exist. The field of railroad track inspection is no exception. Inspection threshold levels (the limits beyond which a condition is considered defective) are established using one of two approaches: 1) prescriptive; and 2) performance-based. Subparts B and C, respectively addressing roadbed and track structure, generally contain prescriptive standards. Prescriptive standards can be considered ones that describe a particular condition, such as an "ineffective tie." Prescriptive standards are sometimes referred to as "hard standards." Hard standards describe conditions that are discrete, meaning the condition is either there or not there. An example is a missing spike. "Hard conditions" are generally easier to detect visually; therefore, visual inspections are often used to detect such conditions. Hard conditions may be somewhat subjective, however, and may require a person's judgment, such as identifying when a tie is "ineffective."

Performance-based standards, such as the track geometry standards in Subpart D, generally require quantitative measurements. As a result, they are typically less subjective, although they are still subject to measurement errors introduced by human error or imperfect machine sensors. Generally speaking, prescriptive standards are more suitable for visual inspections, while performance-based standards are more suitable for automated inspection systems, which are capable of accurately and efficiently taking measurements separated uniformly in space (such as every foot) or in time (such as every millisecond). It would require an exorbitant amount of time for an inspector to continually take such frequent, uniform measurements.

Performance-based measurements are suitable for detecting "soft conditions." Unlike a hard condition, described previously, the term soft condition refers to a condition that takes on a continuum of values. Therefore, a soft condition is always there, and the number of values it can take on is infinite. To make the idea of a soft condition less abstract, one can think of gage measurement as a soft condition. As long as there are two rails, gage will always exist and can take on any value. Due to the measurement that is required to quantify the severity of a "soft issue," it is often more practical to use mechanized systems to detect such issues. This can be evidenced by the widespread popularity of automated track geometry measurement systems (TGMS).

2.3 Probability of Detection Theory

Whether prescriptive or performance-based, the TSS identify which conditions must be sought and remediated when found. The TSS generally provide a threshold safety limit, an inspection frequency, and a remedial action to alleviate each such undesirable condition. The threshold safety limit is generally more quantifiable for performance-based standards. The performance of an inspection system, whether mechanized or visual, can be characterized by its probability of detection (POD) of targeted conditions. This POD may vary based on the magnitude and type of defect. For example, given a uniform inspection speed, the probability that an inspector will visually detect a completely broken-through joint bar is greater than the probability that the inspector will detect an intact joint bar with a hairline surface crack. The POD of a specific type of defect can be quantified for humans and automated systems.

A "perfect system" can be defined as one that finds all defective conditions and has no false positives (commonly referred to as "false alarms") or false negatives (commonly referred to as "misses"). Through a formal presentation of POD theory, it can be shown that the "perfect" system does not exist because every system has inaccuracies or noise associated with it. Due to the presence of noise, a criterion line (or threshold value) must be set. Setting the criterion line at a practical level for a given system is critical. A criterion line that is set too leniently has the potential to produce a large number of false alarms. Generating many false alarms for a particular system may not be a drawback, as it may take a trivial amount of time to follow up and verify whether a "positive" detection is a false alarm or an actual defective condition. However, in other cases, where verification may take longer, a high number of false alarms may not be practical due to the cost associated with having to continually follow up and verify each alarm. At the same time, setting the criterion line more stringently will lead to fewer false alarms, but may lead to an increased number of misses. The number of misses that is acceptable for a system depends on the frequency of inspection and the rate of deterioration of the condition the system is intended to detect. If a system is being used very frequently or if the condition being detected is known to change slowly over time, then a high number of misses may be acceptable. However, if a system is being used infrequently or if the condition being detected deteriorates rapidly, then a high number of misses is not desirable.

A receiver operating characteristic (ROC) curve is a common way of graphically displaying a system's ability to detect defects accurately. It shows that detection of true defective conditions co-vary with false alarms. This is a very important characteristic of any inspection system: increases in the system's true detection rate will increase the number of false alarms. Figure 1 shows two ROC curves. The hypothetical system represented by the red ROC curve is better at detecting defects than the hypothetical system represented by the green ROC curve.

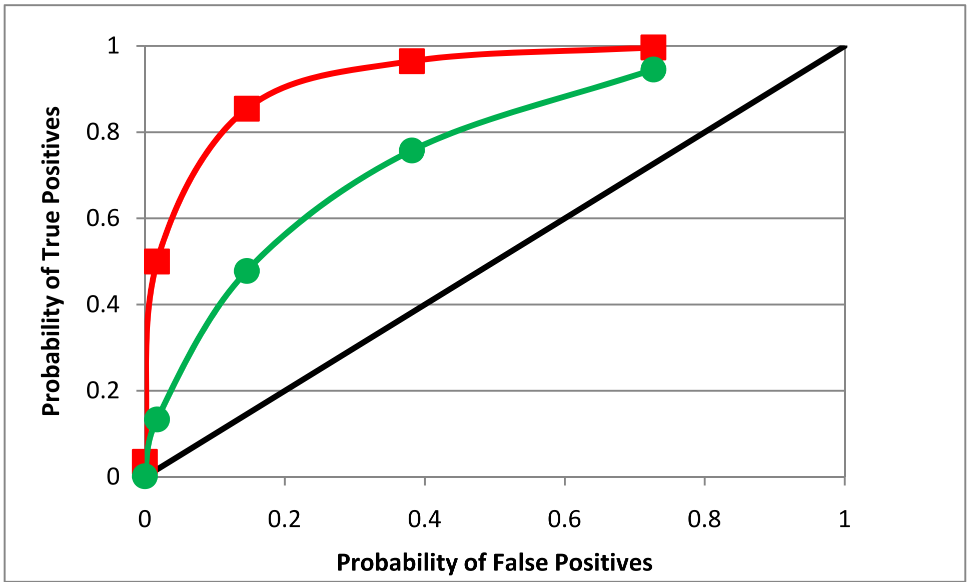

Figure 1. Examples of ROC curves

2.4 Remedial Actions

Once a defective condition is found, the remedial action required will depend on how rapidly the given condition is expected to deteriorate. This rate of deterioration can be based on past empirical data, it can be the result of extensive physical modeling, or it can be a combination of both. Generally, the remedial actions specified in the TSS fall into one of three categories: replace, repair, or reduce. "Replace" refers to a complete replacement of the defective component with an equivalent, non-defective component. "Repair" deals with a temporary or, in some cases, permanent fix or modification to the defective component. For example, once an internal rail defect is indicated and verified to exist, 49 CFR § 213.113 provides that operation over the defective rail is not permitted until the rail is replaced or remedial action specified in a table is taken. "Reduce" refers to a reduction in speed. In order to defer repairing or replacing a defective condition immediately upon discovery, a railroad may opt to reduce the operating speed over the defective condition. Such a reduction in speed is often referred to as a "slow order." A reduction in maximum speed to that corresponding to a class of track for which the condition is not a defect constitutes remedial action. This option is equivalent to the previous two options in the sense that it reduces the overall safety risk associated with a derailment. The repair and replace options are meant to minimize risk by restoring the track structure and preventing a derailment. On the other hand, the reduction-in-speed option is meant to minimize risk by reducing stress on the track, as dynamic forces generally are reduced as train speeds are reduced. The reduction-in-speed option also seeks to minimize damage in the event of a derailment, as historical evidence shows that damage severity and costs resulting from a derailment are reduced as operating speed is reduced. A number of remedial actions specified in the TSS do not fit exclusively into one of the three categories above, but rather may constitute a combination of two or three options. For example, the remedial action table in 49 CFR § 213.113 calls for repairs or reduction in speed, depending on the type of defect detected and the time elapsed before remedial action is taken.

2.5 Frequency of Inspection

The combination of POD—determined from known visual or automated inspection system performance—and the rate of deterioration of the defective condition determines the required frequency of inspection. In some cases, the ideal frequency of inspection may not be feasible. For example, some systems, such as internal rail defect detector cars, operate slower than revenue train traffic. Using such systems frequently may cause extensive revenue losses; therefore, the practical frequency of inspection may involve finding a balance between safety concerns and economic viability.

The TSS prescribe frequency of inspection requirements for visual inspections as well as several automated inspection systems for all classes of track. The frequency requirements for visual inspections are addressed in Subpart F (49 CFR § 213.233) for track classes 1–5 and in Subpart G (49 CFR § 213.365) for track classes 6–9. Required frequencies for automated inspection techniques can also be found in the TSS. For example, frequency requirements for internal inspection of rail on track classes 1–5 are addressed in Subpart F (49 CFR § 213.237), while Subpart G (49 CFR § 213.339) does the same for track classes 6–9. More details on frequencies of inspection provided in the TSS are presented in Section 3.4 of this report.

3. Current Track Inspection Practices and Procedures

The railroad industry currently uses a number of procedures and practices to maintain a safe rail network. Some of these procedures, including visual inspections and several automated inspection techniques, are required by the TSS for certain classes of track. However, other automated systems exist besides those addressed in the TSS, and these are used voluntarily by many railroads. The industry also uses various types of wayside monitoring systems. These wayside monitoring systems are primarily fixed at certain locations either on or near the track, while automated inspection systems traditionally refer to systems installed and used on a moving platform.[4] Sections 3.1, 3.2, and 3.3 outline various practices and procedures, both manual and automated, that are currently used by the railroad industry. Section 3.4 describes which of these procedures are required by the TSS, as well as the threshold levels and required inspection frequencies for each method in inspection.

3.1 Visual Inspections

The railroad industry currently conducts regularly scheduled visual inspections. These visual inspections are either conducted on foot or in a hi-rail vehicle.[5] An inspection may be conducted by a single inspector or multiple inspectors. For example, if multiple tracks are being inspected from a hi-rail vehicle, two inspectors may conduct the inspection together; therefore, each can focus his or her attention on a single track.

Inspectors are expected to look for all track defects addressed in the TSS. Some of the defects that they find, such as excessively decayed ties, may be readily apparent even to a track inspection novice. On the other hand, other track defects are more subtle and require vigilance and proper training in order to be detected. For example, loose bolts on joint bars normally cannot be seen from a hi-rail vehicle; however, an experienced inspector can often detect a loose joint from the sound that is generated as the hi-rail vehicle traverses the joint.

Detecting an ineffective fastener system or rail seat abrasion (RSA) is another example of a defective track condition that requires a track inspector with specialized skills. Oftentimes, directly seeing such a condition from a hi-rail vehicle can be difficult or impossible, but the ineffective fastener or RSA can sometimes be detected through other indirect, visual cues. When a loaded rail car traverses such a defect, there may be a tendency for the rail to roll slightly, resulting in a shift of the tread line on the rail. A trained inspector will be able to notice such a shift in the tread line on the rail and, after ground verification, will be able to attribute it to the proper defective condition. There are many other examples of a track inspector's ability to detect track defects from non-obvious visual cues.

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[4] Throughout this document, automated systems implemented on a moving platform will be referred to as inspection systems, while wayside automated systems will be referred to as monitoring systems.

[5] A hi-rail vehicle refers to a self-propelled vehicle that is manufactured to meet Federal Motor Vehicle Safety Standards and is equipped with retractable flanged wheels so that the vehicle can legally be used on both roads and rails. The name comes from combining "highway" with "rail." A common alternative spelling is "high-rail."

3.2 Automated Inspection Systems

In addition to visual inspections, the railroad industry uses a variety of automated inspection and monitoring systems. These systems are often more efficient at finding the "soft conditions," such as track geometry deviations, discussed in Section 2.2 of this report. Over the past couple of decades, three primary inspection systems have emerged and been adopted by the industry: internal rail inspection, track geometry inspection, and gage restraint measurement systems (GRMS). The purpose of internal rail inspection is to detect rail flaws which develop inside the rail. Such flaws are not detectable from a visual inspection of the rail surface. Internal flaws develop for various reasons, and they often initiate at high-stress areas, such as the rolling contact interface between the wheel and rail. As the rail experiences repeated cyclical loading, these small initiation cracks grow in size and will eventually result in a complete rail break (also known as a service failure) if not detected and removed from the track. Undetected internal flaws pose a serious risk to the railroad. An undetected defect can result in rail failure causing disruption of service and the potential risk of catastrophic consequences such as derailment. In fact, in 2008, there were 9,759 rail breaks on Class I railroads[6] with 132 of the incidents resulting in train derailments.[7]

To maximize rail life, railroads use strategic processes that minimize service failure occurrences, relying on periodic ultrasonic or induction rail testing and strategic renewal of rail that shows obvious evidence of fatigue. Traditionally, ultrasonic techniques are predominantly used to detect internal rail defects, although devices operating on induction principles serve as supplemental, add-on systems to detect defects that may be missed by ultrasonic-based systems. Ultrasonic techniques consist of a mechanical means for striking the rail, which introduces sound waves that travel through the rail. Historically, the mechanical means constitutes a transducer containing a vibrating crystal, but recently systems relying on laser technologies have been developed. Then, receivers are used to receive reflected sound waves. The received sound waves are analyzed to determine whether or not a defect is present. With sufficient transducers, processing power, and operator expertise, the size and orientation of the defect may also be determined.

A second type of inspection system used widely in the railroad industry is a TGMS. Track geometry generally characterizes the vertical and lateral deviations of each of the rails as well as the gage and cross-level measurements, which are, respectively, the horizontal and vertical relationships between the two rail heads. Maintaining proper gage and cross-level is essential, as gage or cross-level that is too large or small could result in a derailment. The vertical and lateral deviations of each of the rails are also important, as poor vertical and lateral alinement[8] can result in high dynamic forces and, potentially, a derailment. Track geometry generally

[6] The term "Class I railroad" refers to a large railroad company. Class I status depends on operating revenue. In the United States, there are eight Class I railroads: National Railroad Passenger Corporation (Amtrak); BNSF Railway Company; Canadian National Railway Company; Canadian Pacific Railway; CSX Transportation, Inc.; Kansas City Southern Railway Company; Norfolk Southern Railway Company; and Union Pacific Railroad Company. The term "Class I railroad" does *not* have any relation to track classes 1–9 in the TSS.

[7] These 132 derailments were reportable events because the total damage amount for each derailment exceeded a threshold set by FRA's railroad accident/incident reporting regulations (49 CFR Part 225). The number of non-reportable derailments is not known.

[8] "Alinement" refers to the horizontal (or lateral) deviation of a rail from a reference plane.

characterizes the health of the track structure. Non-standard gage and lateral deviation values can be indications of poor lateral restraint, which is often the result of failed ties and/or rail fasteners. Likewise, non-standard cross-level and vertical deviation values can be the result of degraded ties, ballast, and foundation support. While manual methods can measure gage and cross level as well as vertical and lateral alinement, automated measurement is more efficient and accurate. Furthermore, automated measurements supplied by a TGMS are obtained by applying a load on the track. As a result, a TGMS measures loaded geometry, which is more desirable, as it shows the ability of the track to withstand a significant vertical load. While manual measurements can take into account evidence of movement under load, manual measurements do not apply a vertical load on the track and, therefore, do not provide the same degree of insight into how the track may be deformed by a load. For these reasons, automated measurement of track geometry has become more widely used over the past couple of decades. Most of the major railroads have specially equipped railcars, typically called "track geometry cars," on which they implement an automated TGMS. These cars can record accurate measurements of track geometry on a foot-by-foot basis, making them much faster and more economical when compared to manual collection of track geometry data. Railroads usually deploy their track geometry cars one to three times per year over a given section of track. Some lines, such as those with high tonnage as well as those that carry passenger and hazardous materials, often receive inspection priority over lower-tonnage, lower-value lines.

GRMS is a third type of inspection system that is used widely in the railroad industry. GRMS measures the ability of the track structure to maintain its gage under a constant, vehicle-applied gage-spreading load; by doing so, it quantifies the strength of a track's gage. GRMS vehicles include a third axle that applies a constant lateral, as well as vertical, load on each of the rails. GRMS typically measures the gage at two points: the first near the third axle and the second several feet away at an unloaded point. Based on the applied loads, the gage strength is then quantified by comparing the loaded and unloaded gage measurements. Measurement of gage strength, through the use of GRMS technology, allows railroads to effectively focus their tie and fastener replacement programs.

Other systems are used by the railroad industry, but their use is not as extensive as internal rail defect detection systems, TGMS, and GRMS. Ground penetrating radar (GPR) systems use electromagnetic waves to capture information on different layers of the track structure, including ballast and sub-structure layers. GPR systems are capable of identifying moisture content, subgrade discontinuities, and other anomalies at various depths in the track structure which could result in poor support as the track settles; as a result, GPR allows for detection of subsurface track structure issues before they are manifested on the surface in the form of poor track geometry.

Systems based on machine-vision inspection technologies to detect anomalies in the track structure are gaining in popularity. These machine vision systems use automated algorithms for extraction of designated features from high resolution 2D images or from 3D light detection and ranging (LIDAR) data. One of the systems that has increased in popularity in the past several years captures high resolution images of joint bars and uses automated algorithms to detect surface cracks. Currently, images of the flagged joint bars are visually reviewed by a human operator, as well, to determine that the joint bar does indeed contain a surface crack. This human review remains an essential part of most machine-vision systems, as automated algorithms for extraction of many features are still being developed and refined. Over time, the amount of human review required will likely decline.

Another system that has recently gained in popularity uses multiple accelerometers to measure accelerations at various points on both the rail car body (above the suspension) and on the truck (at or below the suspension). These systems are generally referred to as vehicle/track interaction (VTI) systems. The acceleration measurements from the truck provide an indication of the dynamic forces that are being input into the track structure. As such, sections of track with repeated high acceleration measurements are likely to experience accelerated rates of deterioration. Furthermore, the accelerometers on the car body can be used for non-safety related functions, such as quantifying ride quality.

3.3 Monitoring Systems

Several types of monitoring systems are used by the rail industry. These systems are mounted on or near the track, rather than being mounted on a moving platform. Some of these systems monitor the health of the track, while others are typically used to monitor equipment condition. Wheel impact monitoring devices for the identification of wheel-flats are an example of equipment monitoring. There are other types of equipment monitoring devices, but they will not be discussed further here; rather, this section will focus on wayside devices that monitor the health of the track structure. Perhaps the most common type of wayside track monitoring device are those that measure longitudinal stress in rails as well as the temperature of the rail and use these two measurements to calculate the rail neutral temperature. Over the past couple of decades, continuous welded rail (CWR) has become increasingly used by the railroad industry. CWR consists of rail segments of 400 feet or more that are welded together to form one continuous rail that can span several miles. CWR allows for a smoother ride and lower track degradation rates when compared to jointed rail. However, the risk of buckling in track with CWR increases as the temperature of the rail increases; this is due to the thermal expansion properties of rail steel. To combat this issue, railroads attempt to raise the neutral temperature of rails at installation. This is accomplished either by thermal heating or mechanical pulling of the rails. These practices allow for higher rail temperatures to occur before the rail experiences compression forces. The temperature at which there is zero longitudinal rail stress is called the rail neutral temperature. Monitoring the rail neutral temperature is important, as this temperature can change (and generally decreases) after installation of the rail. The risk of buckling will increase as the rail temperature rises above the rail neutral temperature. Railroads are installing rail neutral temperature monitoring devices in increasing numbers. These devices use strain gages and rail temperature measurements to calculate the rail neutral temperature. Their primary purpose is to monitor and report when the rail neutral temperature falls below a desired level since the risk of buckling is increased as the rail neutral temperature decreases.

Installation of rail neutral temperature monitoring devices on rail in service can be problematic as most units require that the rail be cut during installation in order to establish the reference neutral temperature. Therefore, some railroads have adopted the approach of installing rail temperature measurement monitoring devices. Such devices simply monitor the temperature of the rail. They are easier to install than rail neutral temperature monitoring devices, but the drawback is that the railroad must estimate the current rail neutral temperature, perhaps based on the amount of heating and/or tension put in the rail at installation as well as historical data on the reduction of rail neutral temperatures over time. As a result, the combination of the measured rail temperature and the educated guess at the rail neutral temperature permit estimation of the buckling risk.

3.4 Track Safety Standards Inspection Requirements

3.4.1 Visual Inspections Required by the Track Safety Standards

The industry currently conducts routine visual inspections which are required by the TSS. Specifically, Subpart F (49 CFR § 213.233) of the TSS addresses the requirements for track classes 1–5, while Subpart G (49 CFR § 213.365) addresses track classes 6–9, which typically would support passenger operations. The TSS prescribe that the visual inspection should be conducted by qualified personnel, either on foot or in a vehicle. However, the TSS also encourage the use of automated technologies to supplement the visual inspection. Relevant portions of 49 CFR § 213.233, paragraphs (b) and (c), specifying the inspection procedures and frequencies for track classes 1–5 are reproduced here:

> *(b) Each inspection shall be made on foot or by riding over the track in a vehicle at a speed that allows the person making the inspection to visually inspect the track structure for compliance with this part. However, mechanical, electrical, and other track inspection devices may be used to supplement visual inspection. If a vehicle is used for visual inspection, the speed of the vehicle may not be more than 5 miles per hour when passing over track crossings and turnouts, otherwise, the inspection vehicle speed shall be at the sole discretion of the inspector, based on track conditions and inspection requirements. When riding over the track in a vehicle, the inspection will be subject to the following conditions –*
>
> > *(1) One inspector in a vehicle may inspect up to two tracks at one time provided that the inspector's visibility remains unobstructed by any cause and that the second track is not centered more than 30 feet from the track upon which the inspector is riding;*
> >
> > *(2) Two inspectors in one vehicle may inspect up to four tracks at a time provided that the inspector's visibility remains unobstructed by any cause and that each track being inspected is centered within 39 feet from the track upon which the inspectors are riding.*
>
> * * *

(c) Each track inspection shall be made in accordance with the following schedule –

Class of Track	***Type of Track***	***Required Frequency***
Excepted track and Class 1, 2, and 3 track	*Main track and sidings*	*Weekly with at least 3 calendar days interval between inspections, or before use, if the track is used less than once a week, or twice weekly with at least 1 calendar day interval between inspections, if the track carries passenger trains or more than 10 million gross tons of traffic during the preceding calendar year.*
Excepted track and Class 1, 2, and 3 track	*Other than main track and sidings*	*Monthly with at least 20 calendar days interval between inspections.*
Class 4 and 5 track	*……………………*	*Twice weekly with at least 1 calendar day interval between inspections.*

* * * * *

Section 213.365 of 49 CFR prescribes visual inspection requirements for track classes 6–9. Relevant portions of paragraph (b) of 49 CFR § 213.365 are identical to those restated above for paragraph (b) of 49 CFR § 213.233. Paragraph (c) of 49 CFR § 213.365 prescribes inspection frequency requirements, and is restated here:

(c) Each track inspection shall be made in accordance with the following schedule –

Class of Track	***Required Frequency***
Class 6, 7, and 8 track	*Twice weekly with at least 2 calendar days interval between inspections.*
Class 9 track	*Three times per week.*

Although not an entirely visual inspection in nature, paragraph (f) of 49 CFR § 213.365 requires a pilot train be run over Classes 8 and 9 track in certain cases:

(f) In track classes 8 and 9, if no train traffic operates for a period of eight hours, a train shall be operated at a speed not to exceed 100 miles per hour over the track before the resumption of operations at the maximum authorized speed.

A visual inspection encompasses many elements of the track structure. These items are addressed in Subparts B, C, and D of the TSS for the lower track classes (Classes 1–5) and in portions of Subpart G for the higher-speed track classes (Classes 6–9). Subpart B addresses the roadbed and surrounding wayside area drainage and vegetation requirements. Subpart C addresses track geometry requirements. Visual inspection for geometry is acceptable for track classes 1–6. However, for Classes 7 and above, automated inspection for geometry deviations is required and will be discussed in more detail in subsequent sections. Finally, Subpart D generally addresses ballast, crosstie, and fastener system requirements.

Visual inspections and automated inspections typically occur on a regularly scheduled basis. However, unscheduled visual inspections, commonly referred to as special inspections, also occur. Oftentimes, these special inspections are the result of severe weather conditions but may also be the result of a derailment or passenger ride quality complaints. Section 213.239 of the TSS addresses the need for special inspections. Specifically, it states the following:

In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection shall be made of the track involved as soon as possible after the occurrence and, if possible, before the operation of any train over that track.

3.4.2 Automated Inspections Required by the Track Safety Standards

As mentioned previously, some of the automated systems used by industry are required by the TSS for certain classes of track. Typically, an automated inspection required by the TSS also requires on-the-ground verification of a defective condition to verify potential "false positive" defect indications resulting from automated system errors. There are five automated inspection techniques prescribed in the TSS for which this ground verification technique is required. First, requirements for internal rail inspections are described in Section 213.237 of the TSS for Classes 1–5. Paragraph (a) of 49 CFR § 213.237 is restated here:

(a) In addition to the track inspection required by § 213.233, a continuous search for internal defects shall be made of all rail in Classes 4 through 5 track, and Class 3 track over which passenger trains operate, at least once every 40 million gross tons (mgt) or once a year, whichever interval is shorter. On Class 3 track over which passenger trains do not operate such a search shall be made at least once every 30 mgt or once a year, whichever interval is longer.

Section 213.339 of the TSS describes internal rail inspection requirements for Classes 6–9. Paragraph (a) of 49 CFR § 213.339 is restated here:

(a) A continuous search for internal defects shall be made of all rail in track at least twice annually with not less than 120 days between inspections.

Rail inspection requirements for Classes 1–5 are currently under review. Since 2007, the RITF has been meeting to recommend regulatory language changes to 49 CFR §§ 213.233 and 213.237. The RITF comprises industry and government representatives, and is a subset of RSAC's Track Safety Standards Working Group. FRA believes that the recommendations arising from this RSAC effort will address the requirements of Section 403(b) of the RSIA, which requires that the Secretary review the most current rail flaw, rail defect growth, rail fatigue, and other relevant track or rail-related research and studies and respond with necessary recommendations.

The RITF has discussed factors that can and should be included in determining the frequency of internal rail flaw testing and a methodology for taking those factors into consideration with respect to mandatory test intervals. In these discussions, the focus has been on the validity of the time intervals and accumulated tonnage limits, which determine the current required rail test frequency. In addition, consideration has been given to recent studies concerning defect development. The challenge to the railroads is to avoid the occurrence of service failures (broken rails) due to undetected defects. Inspecting for and removing rail defects reduces the likelihood of derailments, helps maximize rail service life, and protects service reliability. Given the performance limits of modern rail flaw detection equipment, rail testing frequency is the most effective means for controlling risk. A railroad must choose a rail testing frequency that will balance the cost of testing and defect removal with the expected derailment cost to minimize the net cost of the risk. In this delicate equation, the reliability and efficiency of the testing system play an important role.

The second automated inspection technique addressed in the TSS is a TGMS inspection. Section 213.333 of the TSS prescribes requirements for automated inspection of track geometry for track classes 7 and higher. Specifically, paragraph (a) of 49 CFR § 213.333 reads as follows:

> *(a) For track class 7, a qualifying Track Geometry Measurement System (TGMS) vehicle shall be operated at least twice within 120 calendar days with not less than 30 days between inspections. For track classes 8 and 9, it shall be operated at least twice within 60 days with not less than 15 days between inspections.*

GRMS is the third automated inspection technique addressed in the TSS. Paragraph (h) of 49 CFR § 213.333 prescribes GRMS inspection requirements for Classes 8 and 9, stating:

> *(h) For track classes 8 and 9, a qualifying Gage Restraint Measurement System (GRMS) shall be operated at least once annually with at least 180 days between inspections to continuously compare loaded track gage to unloaded gage under a known loading condition. The lateral capacity of the track structure shall not permit a gage widening ratio (GWR) greater than 0.5 inches.*

In addition to the requirements for Classes 8 and 9, an alternative standard using GRMS is provided for Classes 1–5 in Section 213.110 of the TSS. The prescriptive, non-performance-based standard for gage strength is contained in 49 CFR § 213.109. Paragraph (c) of that section states the following:

> *(c) Each 39 foot segment of: Class 1 track shall have five crossties; Classes 2 and 3 track shall have eight crossties; and Classes 4 and 5 track shall have 12 crossties, which are not:*
> - *(1) Broken through;*
> - *(2) Split or otherwise impaired to the extent the crossties will allow the ballast to work through, or will not hold spikes or rail fasteners;*
> - *(3) So deteriorated that the tie plate or base of rail can move laterally more than ½ inch relative to the crossties; or*
> - *(4) Cut by the tie plate through more than 40 percent of a ties' thickness.*

As an alternative to this prescriptive standard, a railroad may choose to designate certain track as GRMS-territory, in which case the track does not have to comply with 49 CFR § 213.109. Instead, GRMS-designated track for track classes 1–5 is regulated under 49 CFR § 213.110 of the TSS. Paragraph (a) of that section states:

> *(a) A track owner may elect to implement a Gage Restraint Measurement System (GRMS), supplemented by the use of a Portable Track Loading Fixture (PTLF), to*

determine compliance with the crosstie and fastener requirements specified in §§ 213.109 and 213.127 provided that –

(1) The track owner notifies the appropriate FRA Regional office at least 30 days prior to the designation of any line segment on which GRMS technology will be implemented; and

(2) The track owner notifies the appropriate FRA Regional office at least 10 days prior to the removal of any line segment from GRMS designation.

The fourth automated inspection required by the TSS concerns acceleration measurement requirements. Specifically, relevant portions of paragraphs (j) and (k) of 49 CFR § 213.333 state the following:

*(j) At least one vehicle in one train per day operating in Classes 8 and 9 shall be equipped with functioning on-board truck frame and carbody accelerometers. * * **

(k) For track classes 7, 8 and 9, an instrumented car having dynamic response characteristics that are representative of other equipment assigned to service or a portable device that monitors on-board instrumentation on trains shall be operated over the track at the revenue speed profile at a frequency of at least twice within 60 days with not less than 15 days between inspections. The instrumented car or the portable device shall monitor vertically and laterally oriented accelerometers placed near the end of the vehicle at the floor level. In addition, accelerometers shall be mounted on the truck frame.

The threshold safety limits for the measured accelerations are not reproduced here but can be found in the table of Vehicle/Track Interaction Safety Limits in Section 213.333 of the TSS.

The usage of instrumented wheelsets for the measurement of dynamic forces is the fifth automated inspection required by the TSS. Paragraph (l) of 49 CFR § 213.333 states in relevant part the following:

*(l) For track classes 8 and 9, an instrumented car having dynamic response characteristics that are representative of other equipment assigned to service shall be operated over the track at the revenue speed profile annually with not less than 180 days between inspections. The instrumented car shall be equipped with functioning instrumented wheelsets to measure wheel/rail forces. * * **

The threshold safety limits for wheel/rail forces are not reproduced here but can also be found in the same table cited above.

3.4.3 Summary of Inspections Required by the Track Safety Standards

Table 2 summarizes the visual and automated inspections required by the TSS as well as the maximum operating speed for passenger and freight trains for each class of track. Automated inspection techniques are highlighted in light blue in Table 2. With the exception of periodic inspections for rail defects, automated inspection requirements exist exclusively for track classes 6 and above.

Table 2. FRA track inspection requirements for each class of track

		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9
Maximum Operating Speed (mph)	*Passenger*	15	30	60	80	90	110	125	150	200
	Freight	10	25	40	60	80				
Track Inspection Requirements										
Visual Inspections (Track)		2 weekly (passenger)	2 weekly	2 weekly	2 weekly	2 weekly	2 per week	2 per week	3 per week	3 per week
Visual Inspections (Switch/Crossing)		1 per month	1 per month	1 per month	1 per month	1 per month	1 per week	1 per week	1 per week	1 per week
Functional Inspections (Switches held by mechanism and single rod exercised in all positions)				1 per 3 months	1 per 3 months	1 per 3 months				
AUTOMATED Load Measuring Wheels (IWS)							During System Qualification	During System Qualification	During System Qualification, Annually	During System Qualification, Annually
AUTOMATED Accelerometers - Truck Frame							During System Qualification	1 per month	1 per day	1 per day
AUTOMATED Accelerometers - Carbody							1 per 3 months	1 per month	1 per day	1 per day
AUTOMATED Geometry Car								1 per 60 days	1 per 30 days	1 per 30 days
AUTOMATED Pilot or Inspection Train									If no operation in 8-hr period, next train restricted to 100 mph.	If no operation in 8-hr period, next train restricted to 100 mph.
AUTOMATED Gage Restraint Measurement System									1 per year	1 per year
AUTOMATED Rail Flaw				w/PSGR: 1 per 40 mgt or 1 per year whichever shorter NO PSGR: 1 per 30 mgt or 1 per year, whichever longer	1 per 40 mgt or 1 per year, whichever shorter	1 per 40 mgt or 1 per year, whichever shorter	2 per year	2 per year	2 per year	2 per year

3.5 FRA's Role

FRA's Office of Railroad Safety serves, among other things, as an independent quality check on the railroad industry. FRA's Office of Railroad Safety includes eight regional offices in addition to a headquarters office located in Washington, DC. Each regional office includes a number of specialists, including a track specialist. The track specialist typically supervises 8 to 12 track inspectors per region. Due to the limited number of FRA track inspectors, FRA is generally limited to conducting "spot-check" visual inspections which serve as a quality check on the railroad industry's track inspection processes and personnel. The locations chosen for these FRA spot-check inspections are determined by the National Inspection Plan (NIP), which is a safety plan formulated and updated annually by FRA's Office of Railroad Safety. The purpose of the NIP is to optimize FRA's ability to reduce the rates of various types of train accidents, releases of hazardous materials, and casualties from human factor errors. The plan provides guidance, based on data-driven models, to each regional office on how its inspectors should divide their work by railroad and State. This is accomplished using data collected during visual inspections and under FRA's Automated Track Inspection Program (ATIP). ATIP is aimed at automated collection of track data. Currently, ATIP uses four railcars capable of collecting geometry data and a fifth car that is capable of collecting both geometry data and GRMS data. ATIP management is located primarily at FRA headquarters in Washington, DC. However, the data collected is disseminated to the respective regional offices and FRA track inspectors. These inspectors may use the data to focus their track inspection spot-checks.

4. Results of Study

This section contains the results of the track inspector survey, highlights from the interviews with railroad management and labor union officials, the results from a theoretical model of observer detection accuracy, and data on defects identified by FRA inspectors.

4.1 Track Inspector Survey Results

The track inspector survey results are presented in this section. Appendix B contains a copy of the survey form. The survey was mailed on April 19, 2010, to 661 track inspectors, and responses received by June 25, 2010, were included in the study results.

4.1.1 Sample Size Methodology and Response Rate

One of the most important issues in conducting the survey of track inspectors was to determine the sample size necessary to guarantee results that were reliable enough to meet the objectives of the study. In general, the larger the sample size, the greater the reliability of the resulting estimates, but this typically has to be traded off against the expense of a larger sample. It was determined that 95 percent confidence was adequate to obtain descriptive information about the track inspection process. Additionally, it was assumed that the estimate should be within 7.5 percent of the "true" value (i.e. a range of 15 percent). There are an estimated 2500 track inspectors working in the United States. The only practical way of reaching these individuals is through their labor organization, the Brotherhood of Maintenance of Way Employes[9] Division (BMWED). Inspectors at one of the eight Class I railroads are not members of BMWED, so reaching this group was not feasible; however, the track inspectors for the seven remaining Class I railroads are represented in the survey results. BMWED provided a list of 1536 actively working track inspectors who were candidates to participate in the survey. The following formula was used to calculate the necessary sample size:

$$n \geq \frac{z^2 N V_x^{\ 2}}{z^2 V_x^{\ 2} + (N-1)\varepsilon^2}$$

where z is the reliability coefficient (1.96 for 95 percent confidence level); N is the population size; ε is the error tolerance; and V_x is the unknown population variance.

The derivation of this formula will not be presented here, but can be found in the literature (Levy et al.). From above, it is seen that z, N, and ε have already been defined; their respective values are 1.96, 1536, and 0.15. In order to solve the equation for the sample size (n), an estimate of a population variance (V_x) for a parameter of interest must be obtained. In this study, primary parameters of interest are a track inspector's ability to approximate the time spent doing specific tasks, speed of inspection, and distance traveled during an inspection. For the purposes of determining a sample size, at least one of these parameters had to be estimated. It was decided that the sample size would be based on an inspector's ability to estimate distance traveled. This

[9] This is an alternative spelling of the word "employee" and is the spelling preferred by BMWED.

parameter was chosen instead of the time and speed parameters primarily because empirical estimates of population variance for estimating distance traveled were found in previous studies (Boff et al., pp. 896–897). Based on this study, the population variance for estimation of distance traveled was 1.18. It can be reasonably expected that population variance for estimation of distance traveled among track inspectors would be less than 1.18 due to the presence of distance markers, such as mileposts. Therefore, it can be assumed that using a population variance value of 1.18 was a conservative estimate of variance and that actual variance among track inspectors would be less than this value.

In accordance with the above formula, a sample size of 205 would be adequate to ensure valid results. Previous surveys of this railroad population achieved a response rate of 31 percent (Gertler 2006). To assure an adequate number of valid surveys, assuming this response rate, a random sample of 661 track inspectors was chosen. After final count, survey responses totaled 237, yielding a response rate of 36 percent.

4.1.2 Potential Survey Biases

As noted previously, the survey was mailed on April 19, 2010, and responses received by June 25, 2010, were included in the survey results. A number of questions in the survey asked respondents to indicate how often they performed a particular task in the past month. Therefore, FRA acknowledges that some survey responses may have biases due to the time of year that the survey was conducted. For example, the spring season often sees increased issues related to ballast fouling due to seasonal rain as well as melting snow. Also, rail maintenance de-stressing operations are performed in the spring. Rail de-stressing operations refer to the adjustment of rail neutral temperature by cutting a rail and placing it in tension; performing this activity reduces the risk of buckling throughout the summer. Furthermore, it is also reasonable to expect a lessening of special inspections due to extreme heat and/or cold during the spring season. For at least these reasons, FRA acknowledges that slight biases may exist in the survey; however, the majority of the data is still applicable to general track inspection issues, without regard to the time of year.

4.1.3 Experience

The number of years of experience as a track inspector varied, and a histogram of the frequency of responses is shown in Figure 2. The mean number of years as an inspector is 12.3, and the median is 14.0. Due to the asymmetry of the distribution, the median may be a better measure of central tendency in this case.

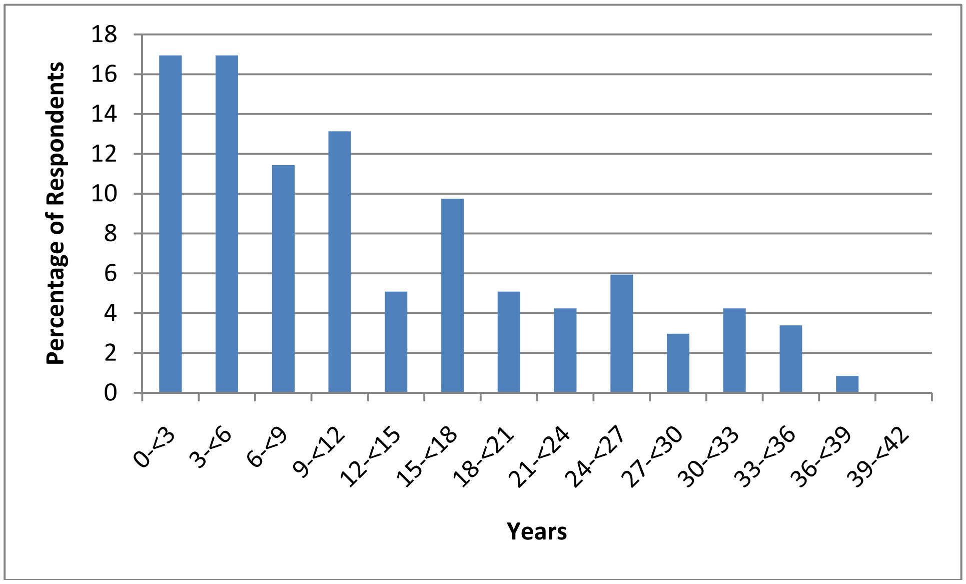

Figure 2. Number of years as a track inspector

The number of years that each of the respondents had spent on their current territory also varied. Figure 3 shows a histogram of the frequency of responses. The mean number of years on an inspector's current territory is 10.9, and the median is 7.0. Once again, due to the asymmetry of the distribution, the median may be a better measure of central tendency.

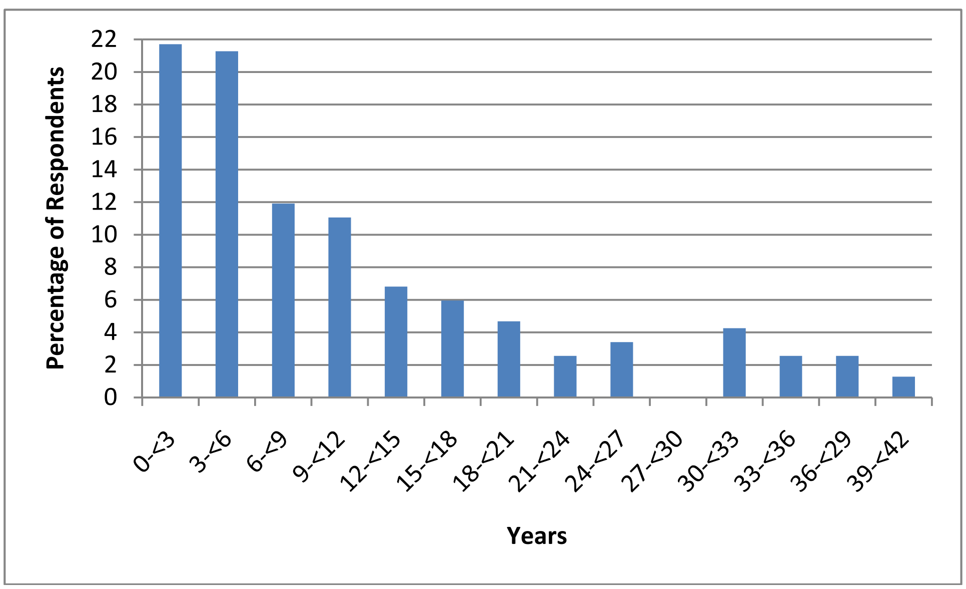

Figure 3. Number of years on current territory

The mean and median for the histogram in Figure 3 are lower than the mean and median for the histogram in Figure 2. This is a strong indication that inspectors typically will change territories at least once during their track inspection careers.

4.1.4 Initial and Subsequent Training

A question addressing initial track inspection training was presented in a multiple choice format with respondents instructed to select all that apply. Approximately 90 percent of respondents had some form of on-the-job training as their initial training, and approximately 53 percent of respondents had formal, company training as an introduction to the track inspection process.

A followup question was asked related to subsequent training. The responses are summarized in Figure 4. While periodic training on the FRA TSS is not required training, over two-thirds of respondents stated that they are provided with FRA TSS training either every year or every other year. Nearly 75 percent of respondents stated that they receive FRA safety standards training every year, yet FRA believes that most respondents were likely referring to FRA roadway worker protection (RWP) training, which is mandatory annual training under 49 CFR 214. Some respondents gave a brief description of "other track related training" that they had received; there were a number of different types of training mentioned, but the two predominant responses were:

- Formal training related to longitudinal track stability (including CWR and track buckling training)
- Training via lessons learned from random audits conducted by either direct supervisors or other management officials

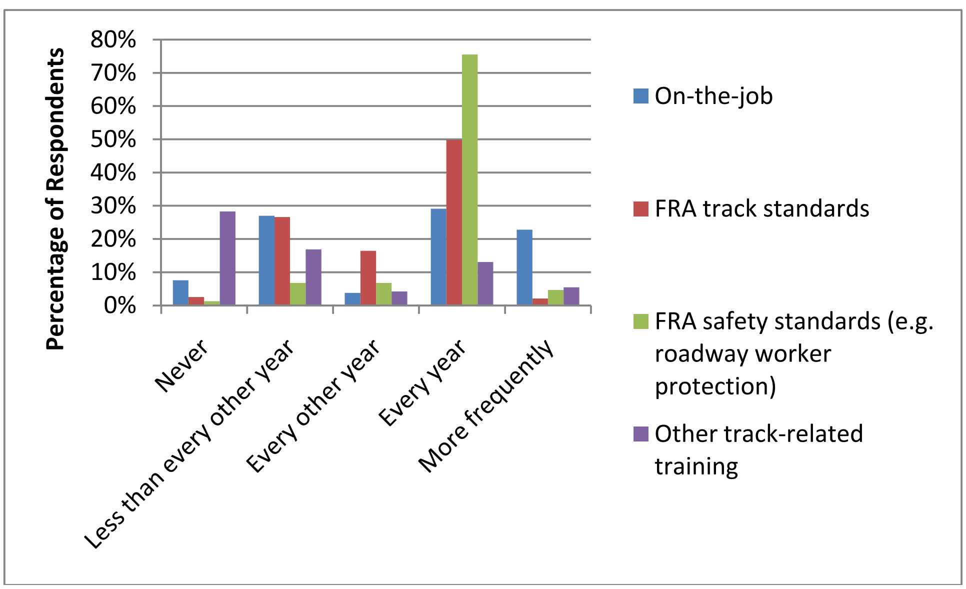

Figure 4. Subsequent track inspection training

4.1.5 Supervisory Oversight

Respondents were asked to indicate how frequently, in the past year, their track supervisor accompanied them on an inspection. The results are presented in Figure 5. Nearly 70 percent of respondents indicated that their supervisor accompanied them quarterly or more frequently.

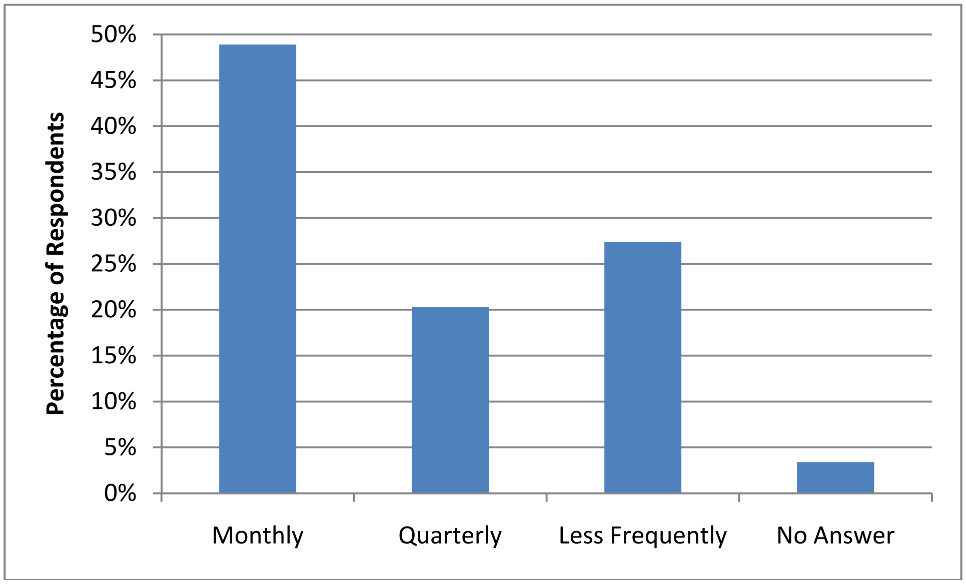

Figure 5. Frequency of supervisory oversight

4.1.6 Length of Workday and Overtime Burden

The survey asked respondents to indicate the official length of their workday. Nearly 85 percent of respondents indicated that they had an 8 hour workday with 10 percent indicating that their workday was 10 hours. The remaining 5 percent had scheduled workdays of either 8.5, 9, 9.5, 12, or 14 hours.

To determine the level of effort expended above and beyond one's scheduled workday, the survey asked respondents to indicate how many days in the past month they worked more than the scheduled length of their workday. The results are presented in Figure 6. Over half of the respondents indicated that in the past month they had worked overtime at least 1 day but not more than 10 days. The mean number of overtime days was 3.1 days and the median was 3.0 days.

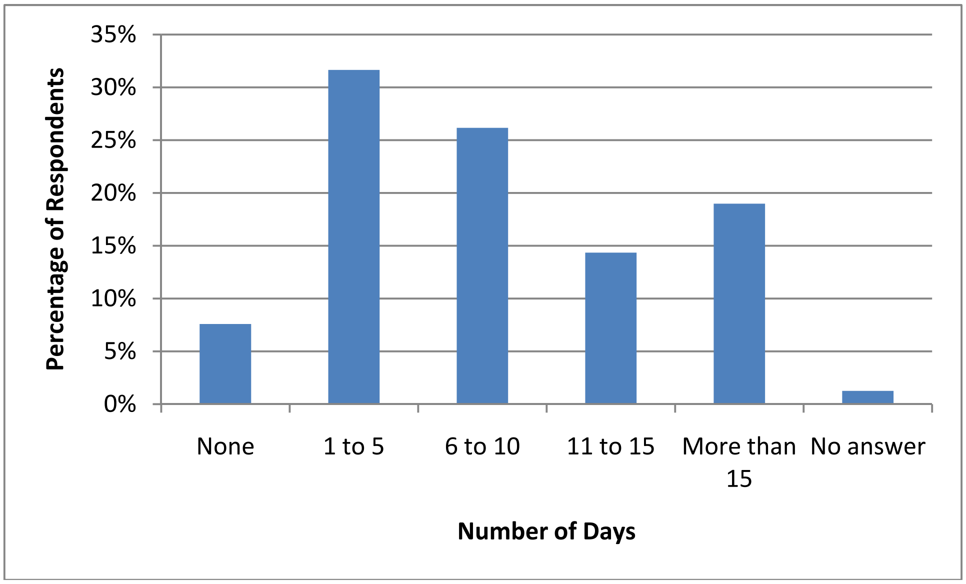

Figure 6. Number of days in the past month worked more than scheduled length of workday

To further determine the amount of additional effort expended above-and-beyond one's scheduled workday, respondents were asked to indicate how many times in the past month they worked on a non-scheduled workday (also referred to as a rest day). The results are presented in Figure 7. Approximately a quarter of respondents said that they did not work on a rest day. The remaining respondents worked on one or more rest days with over 50 percent of respondents indicating that they worked on 1 to 3 rest days. Both the mean and median number of rest days worked was 3.0.

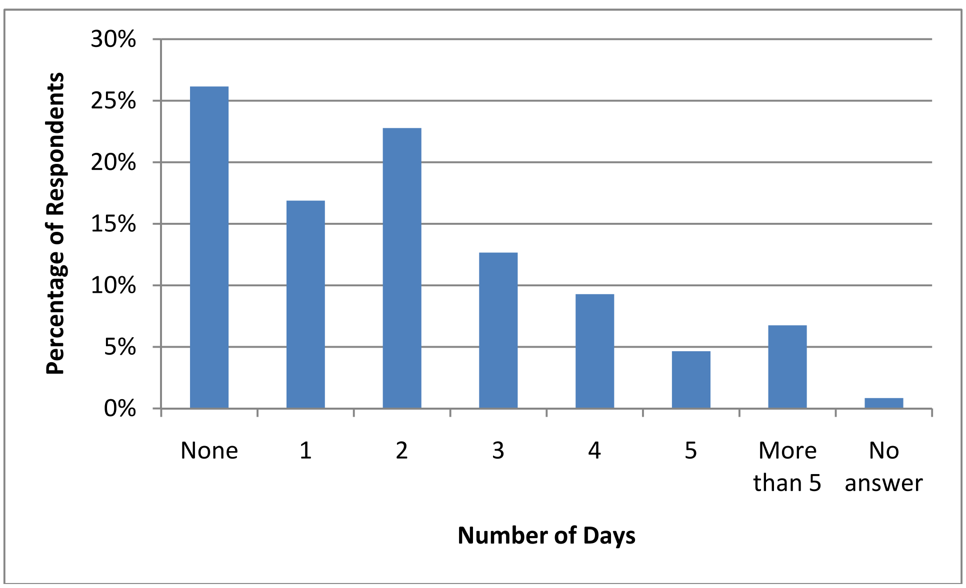

Figure 7. Number of rest days worked in the past month

4.1.7 Time Allocation

In an effort to determine how track inspectors allocate their time throughout the day, respondents were asked to indicate the number of hours that they spend performing inspection duties and repair duties on a typical day. The results are shown in Figure 8. The mean and median for track inspection time are both 5.0 hours, and the mean and median for repair duties is 1.9 hours and 2.0 hours, respectively.

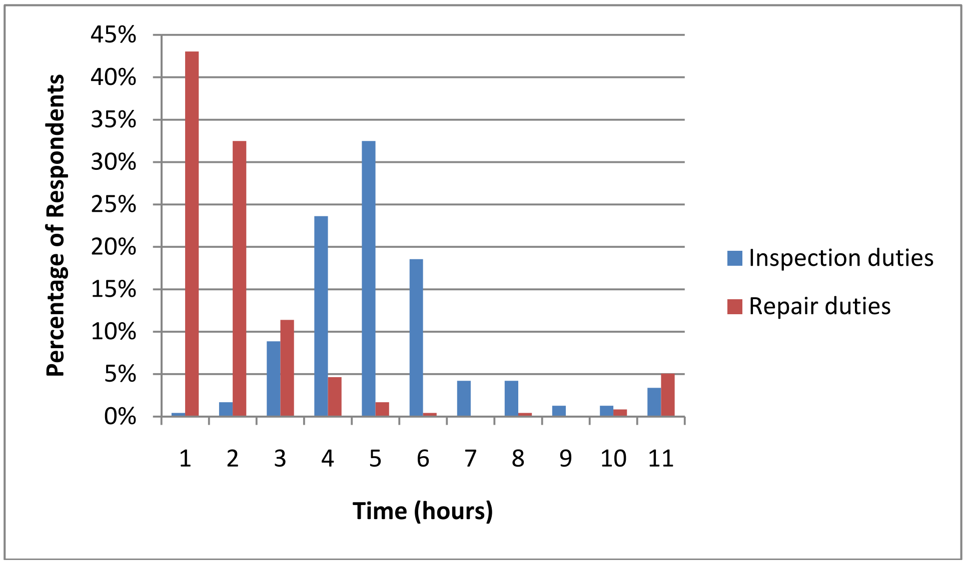

Figure 8. Time spent performing inspection and repair duties

Additionally, respondents were asked to indicate how much time they spend doing each of the following activities on a typical day: job briefings; reporting inspection results; travel time; waiting for track time. The results are indicated in Figure 9. The median reported interval for "job briefings" is 16 to 30 minutes, and the median reported interval for "travel time," "waiting for track time," and "reporting inspection results" is 31 to 45 minutes. The "travel time" and "waiting for track time" parameters have larger standard deviations than "job briefings" and "reporting inspection results." This is an indication that the time spent performing activities other than inspection and repair varies widely between inspectors.

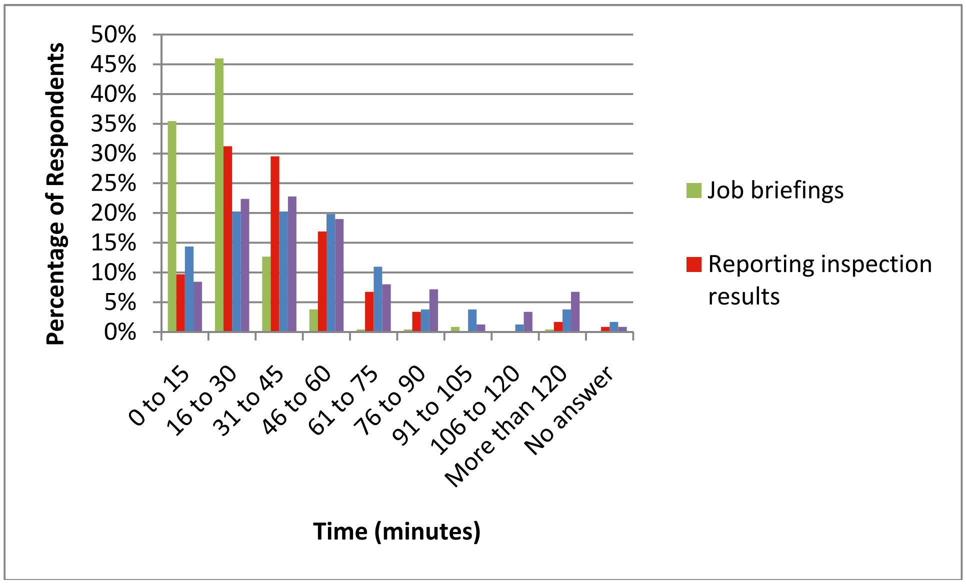

Figure 9. Time spent performing other activities (besides inspection and repair)

4.1.8 Total Territory Size

In order to determine the amount of track for which an inspector is responsible, respondents were asked to indicate the number of mainline track miles in their territories. The histogram in Figure 10 indicates the distribution of the results. The data indicates a mean of 78.9 miles and a median of 75.0 miles. The term "track miles" was clearly defined in the survey. "Track miles" refers to total miles of track; for example, 10 miles of double track constitutes 20 track miles.

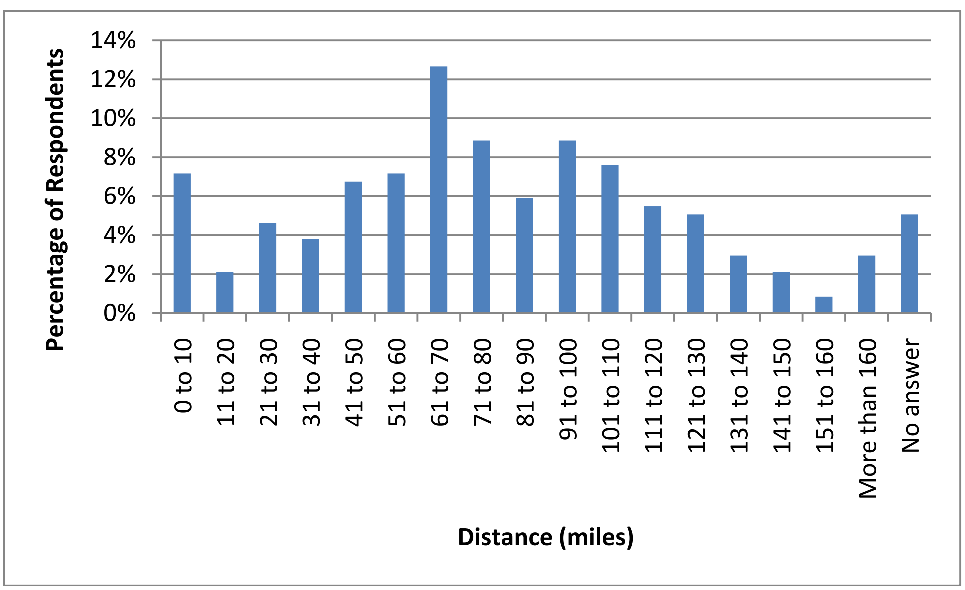

Figure 10. Number of mainline track miles in territory

4.1.9 Track Miles Covered Per Day

Respondents were asked to indicate the number of miles of track they inspect on a typical day. The results are shown in Figure 11. FRA believes that data in the "More than 180" bin represents outliers which may be the result of respondents' misinterpretation of the question.

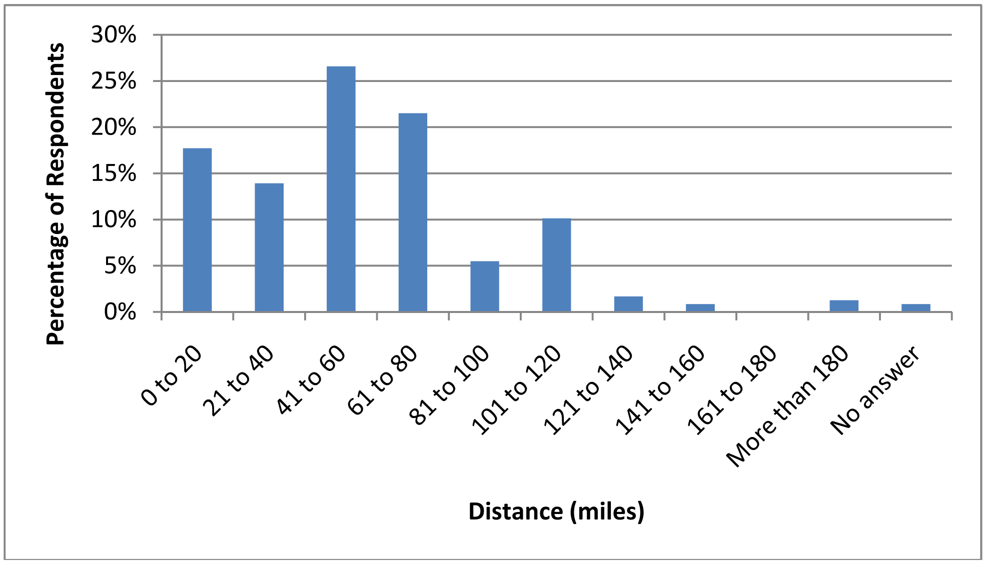

Figure 11. Number of track miles inspected on a typical day

Each of the respondents indicated whether they inspect by: 1) hi-rail vehicle only, 2) hi-rail vehicle mostly and on-foot sometimes, 3) on-foot mostly and hi-rail vehicle sometimes, or 4) on-foot only. The data presented in Figure 11 was separated into these four categories. The number of respondents in each group, as well as the mean and standard deviation for each group, is shown in Table 3.

Table 3. Primary method of visual inspection

	Count	**Mean** (miles per day)	**Standard Deviation** (miles per day)
Hi-rail only	14	79.1	43.3
Hi-rail mostly, on-foot sometimes	163	64.8	31.6
On-foot mostly, hi-rail sometimes	17	10.4	8.0
On-foot only	12	9.2	5.8

4.1.10 Inspection Speed

To determine typical inspection speeds, the survey asked respondents who use hi-rail vehicles to indicate the speed of their inspection on tangent CWR track[10] and tangent jointed track, as well as on curves. Figure 12 shows that the speed distributions for tangent jointed track and curves (the second and third bars in each category) are very similar with approximately 50 percent of

[10] In the railroad industry, the term "tangent track" is commonly used to refer to track that is straight.

respondents indicating that they travel at a speed of 11 to 20 mph and approximately 30 percent of the respondents indicating that they travel at a speed of 1 to 10 mph. On tangent CWR track (the first bar in each category), approximately 50 percent of respondents indicated that their average speed of inspection is between 21 to 30 mph and approximately 30 percent of respondents indicated that their inspection speed is 11 to 20 mph. The data depicted in Figure 12 indicates that inspection speeds on tangent CWR track is typically higher than on tangent jointed track and curves.

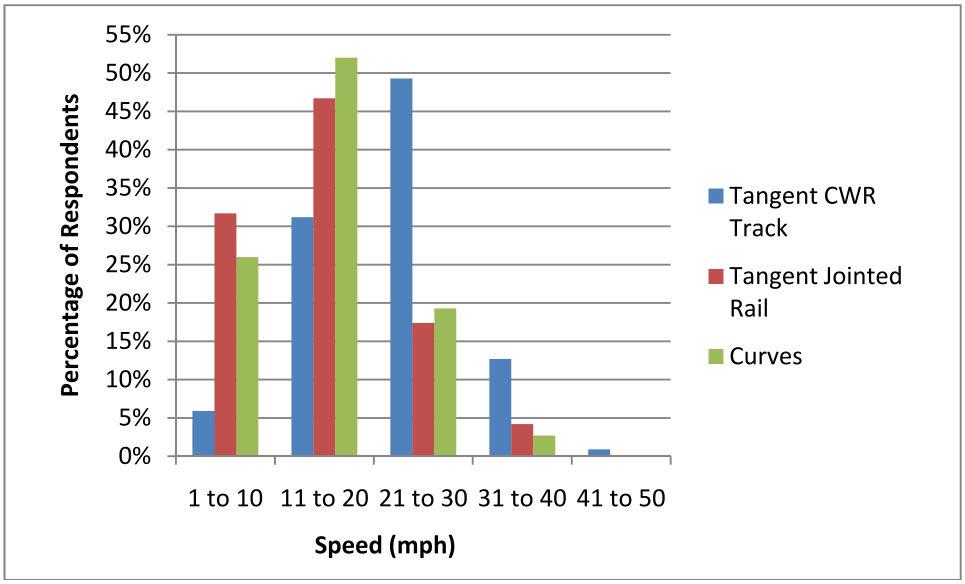

Figure 12. Reported hi-rail inspection speeds

The survey also asked respondents to indicate conditions that cause the speed of inspection to be adjusted. The multiple choice options included: time pressure to complete work; weather; interlocks; inadequate track time; highway crossings; dispatcher decisions; other (please specify). The results are displayed in the histogram in Figure 13. Approximately 60 percent of respondents indicated that weather, time pressure to complete work, dispatcher decisions, and inadequate track time were all factors that cause variations in inspection speed; it is assumed that most of these variations would typically result in an increased average inspection speed.

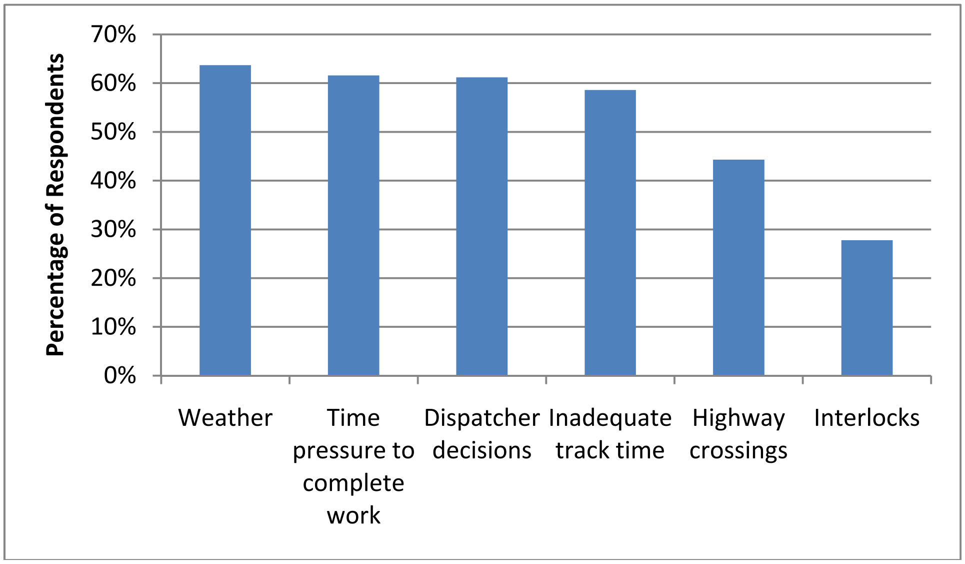

Figure 13. Conditions that cause adjustments to typical inspection speeds

4.1.11 Detection of Track Defects

The survey asked respondents to indicate how they typically identify various track defects. The results are shown in the table in Appendix C. Respondents were asked to indicate all the methods used to find each condition. In other words, for a given track condition, a respondent could mark off both "Visual – On foot" as well as "Visual – Hi-rail." As a result, the numbers in each row will not necessarily sum to 100 percent.

As the table in Appendix C indicates, RSA and burned bolt holes in rail had higher values of "Not Readily Detectable" relative to other track conditions. The practice of burned bolt holes in rail is no longer allowed, so the number of these occurrences in track is likely gradually decreasing. However, detection of RSA continues to be a problem.

The table also indicates that approximately 30 to 35 percent of track inspectors use automated data from TGMS inspections in order to help direct them to areas with alinement and profile deviations, as well as gage and cross-level issues. This range of 30 to 35 percent of inspectors utilizing automated data is large relative to utilization of automated data to find non-geometry related track defects; most non-geometry-related track defects had 2 percent or less of respondents indicating that they use automated data to aid them in finding the defective condition.

4.1.12 Calculated Inspection Speed

As a validity check on the data, inspection speeds were calculated for those respondents who indicated that they inspected primarily by hi-rail and sometimes or rarely on foot. The calculated speed of inspection for each inspector in this group was determined by dividing the reported time spent inspecting on a typical day by the reported number of miles inspected. Figure 14 displays the results. The data has a mean of 13.9 mph and a median of 12.0 mph. The distribution of these values generally indicates slightly lower speeds than the distributions shown in Figure 12.

However, the speeds shown in Figure 12 are values that inspectors reported for inspections on hi-rail vehicles. The calculated inspection speeds inherently include some time on foot for ground verification of potential defects and explains why these values are slightly lower than the reported hi-rail inspection speeds.

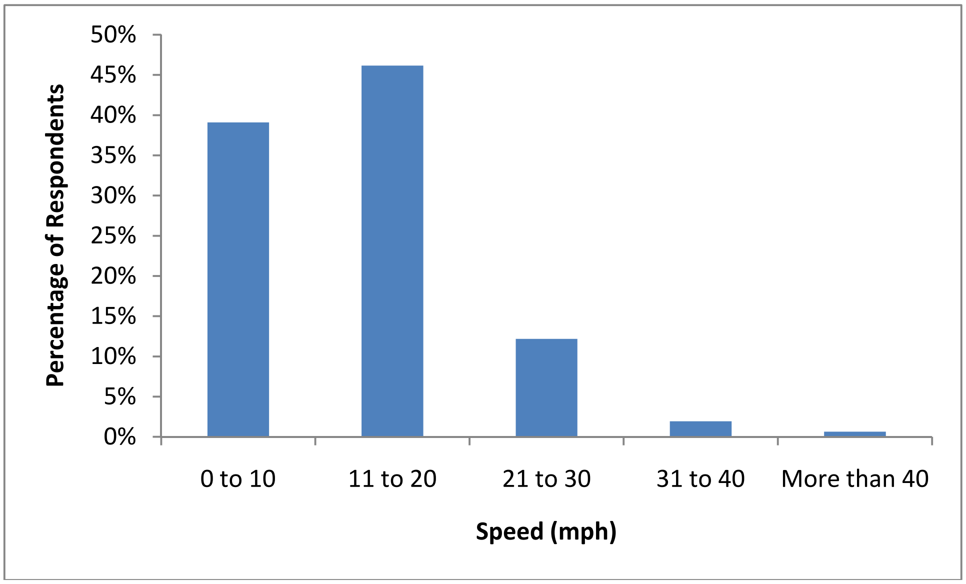

Figure 14. Calculated inspection speeds

4.1.13 Calculated Inspection Frequency

Generally, the TSS require that track classes 1–3 be inspected at least once a week, and track classes 4 and 5 be inspected at least twice a week (for complete details, see Section 213.233 of the TSS). As a check on the data quality, as well as to determine approximate frequency of inspection, the inter-inspection time (the number of days between inspections) was calculated by dividing a respondent's territory size (in track miles) by the number of track miles that the inspector covers on a typical day. The resulting number represents the number of days to cover the entire territory, assuming that only mainline track is inspected. The data is filtered to include only those individuals who inspect mostly by hi-rail and do not (or rarely) inspect by walking. Individuals whose responses indicate that they inspect more miles daily than the total number of mainline miles in their territory were excluded.

Figure 15 indicates the frequency of inspection for those inspectors inspecting only track classes 1–3, and Figure 16 does the same for those inspectors inspecting only track classes 4 and 5. As can be seen from the histogram distributions, the great majority of inspectors on Classes 4 and 5 cover their territory every 1 to 2 days, while inspectors on Classes 1–3 cover their territory every 1 to 3 days. These inter-inspection times generally are more frequent than the requirements prescribed in Section 213.233 of the TSS. In fact, according to the survey data, there are no cases where practiced track inspections frequencies do not comply with TSS requirements.

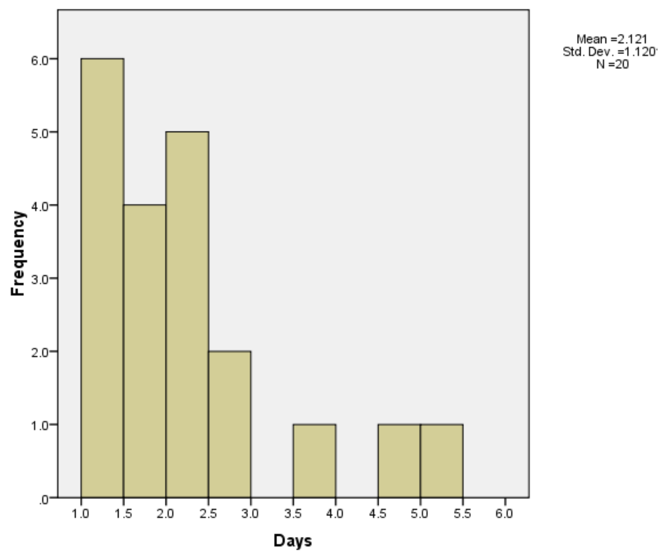

Figure 15. Calculated inspection frequency for track classes 1–3 and excepted track

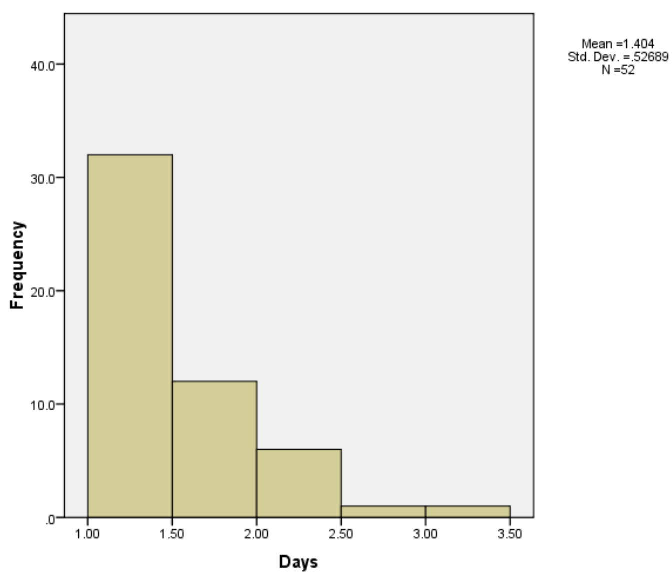

Figure 16. Calculated inspection frequency for track classes 4 and 5

4.1.14 Relevant Correlations

Correlation coefficients are often used to find relationships between two (or more) random variables. A value of 0 indicates that there is no correlation between two variables, and a value of 1 indicates perfect correlation. A more complete explanation of correlation coefficients can be found in introductory books on statistics, such as Keeping (1995).

For the purposes of this report, a correlation coefficient was calculated to determine if there is a correlation between an inspector's territory size and speed of inspection. A correlation coefficient of 0.5 was calculated; therefore, as territory size increases, speed of inspection will generally increase. This relationship is visually evident in the scatter plot shown in Figure 17. The territory size here refers to track miles, not route miles. If a route mile dataset were available from the survey, one would expect an even stronger correlation than is shown in the scatter-plot in Figure 17.

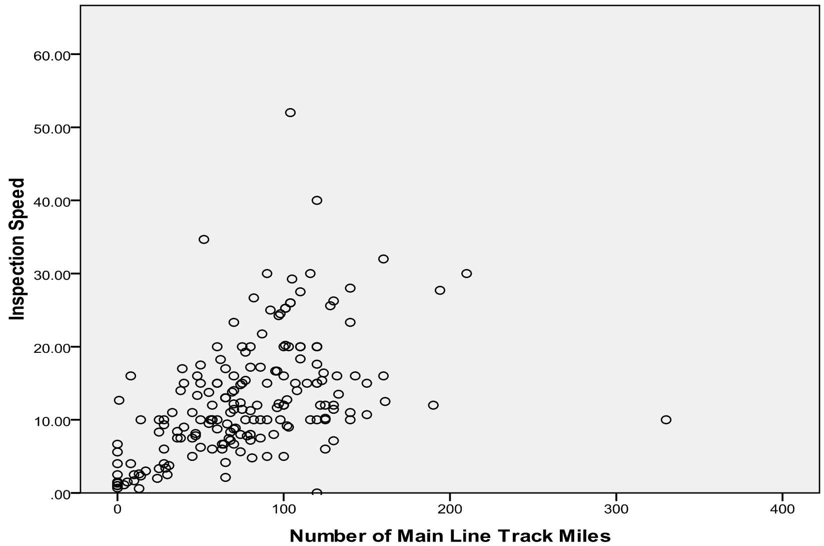

Figure 17. Correlation of number of mainline track miles and inspection speed

4.1.15 Summary of Track Inspectors' Comments

The final portion of the survey asked respondents to comment on any other aspect of the track inspection process that they would like FRA to consider in preparing its report to Congress. Of the 237 completed surveys, 74 included comments. The topics addressed in the comments varied widely; however, four subjects were brought up frequently:

- Non-inspection duties (11 comments)
- Maintenance (7 comments)
- Track time (6 comments)
- Hours of service (5 comments)

Comments on non-inspection duties were the most prevalent. Respondents indicated that they often had to perform duties not directly related to visual track inspection, such as riding in internal rail defect detector cars, participating in hi-rail geometry car pilot programs, and directing surfacing gangs. They said that doing such tasks often takes time away from their primary track inspection duties.

The comments relating to maintenance generally stated that the railroad does not have enough maintenance crews and equipment to perform all the necessary repairs. A couple of the comments directly stated that the inspection process is not the major issue; rather, manpower to fix the problems found was identified as the primary cause for concern.

Comments addressing track time pointed out that it is not uncommon for an inspector to get forced off the track due to dispatcher decisions. This results in increased inspection speeds in order to get over an assigned territory, or it results in a portion of the territory not getting inspected. One comment summarized the issue by stating that almost all personnel in the railroad want to get trains moving across a given territory at as fast a speed as possible, while the job of the track inspector is to slow down (or completely stop) traffic if an unsafe condition exists. Due to the perceived lost revenue from this reduced traffic flow, inspectors oftentimes have trouble getting track time because increased track time may result in an increase in the number of slow orders.

Comments that were directed towards the "hours of service" issue generally stated that track inspectors often have to work excessive hours of overtime. In many cases, this overtime (whether paid or unpaid) may not be desired by a track inspector; however, it is oftentimes required by the railroad. Respondents commented that track inspectors can, in certain circumstances, be expected to work 16 to 20 hours a day; therefore, one comment referred specifically to the hours of service laws for roadway worker protection and suggested that similar hours of service laws should exist for track inspection.

4.2 Salient Points from Labor Union and Railroad Management Interviews

To substantiate the responses in the track inspector survey and assure that a total picture of the track inspection process was obtained, phone interviews were conducted with labor union leadership and three levels of railroad management: track supervisors, division engineers, and chief engineers. Track supervisors (or roadmasters) are the direct supervisors of track inspectors. Typically 5–10 inspectors report to a single track supervisor. Division engineers are often the direct supervisors of track supervisors. Track supervisors are in charge of a subdivision; whereas division engineers are in charge of an entire division, which is comprised of multiple subdivisions. Chief engineers (or system-level officers) are typically in charge of a railroad's entire network or a substantial percentage of the network. Class I railroads typically have 1 to 4 chief engineers. Chief engineers are usually the direct supervisors of division engineers. Unlike the track inspectors, the individuals in each of these groups were not randomly selected; instead, the members of each of these groups constituted a convenience sample.[11] This was necessary as the neutral, third-party contractor conducting the interviews was only given access to those labor union and railroad officials who had the available time to participate in the interview process.

The purpose of conducting interviews with these various groups was to obtain different perspectives on the state of track inspection. FRA believed that information obtained during the interviews would provide additional context to survey responses. Detailed summaries of each of the interview groups are in Appendices D–G.

Standardized training for track inspectors was a point emphasized by several labor union officials. In addition, union officials believe that track supervisors, rather than track inspectors, are currently not receiving enough training. They noted that railroads are hiring track supervisors that have no prior experience performing track inspection. This comment by labor union officials appears to be validated by data obtained from track supervisors during their

[11] A "convenience sample" (also known as an "accidental sample") is a type of sampling not based on principles of probability but rather involves the sample being drawn from members of the population that are easily accessible or convenient.

interviews, as seven out of twelve of the track supervisors interviewed had no prior track inspection experience; however, they may have had experience performing track maintenance duties.

Labor union officials stated that there is pressure to do more work in less time. They said that this is partly due to the fact that in recent years there has been a trend toward increased non-inspection duties, such as repair duties, for track inspectors. Labor union officials were split on whether there are enough track inspectors, but railroad officials (including track supervisors, division engineers, and system-level officers) generally agreed that there are enough track inspectors to maintain a safe, viable rail network. Still, five out of twelve track supervisors commented that their inspectors have to work overtime occasionally or frequently. The reasons most often cited were lack of track time and inclement weather. Therefore, railroad industry management appears to believe that the amount of work expected of track inspectors is reasonable; however, track supervisors realize that railroad operating practices, along with inclement weather conditions, may create the occasional or frequent need for overtime.

Labor union officials commented that track inspectors oftentimes feel pressure, either real or perceived, from management not to issue slow orders, as slow orders may result in lost revenue. Inspectors are routinely faced with this decision of whether or not to issue a slow order, balancing safety and the desires of railroad management. Furthermore, even if a defect is reported and a slow order is issued, union officials said that there are generally not enough repair crews to fix all the issues that track inspectors find; similar comments were made by several track supervisors. As a result, track inspectors often have to prioritize track repairs.

Several track supervisors provided comments on their interactions with FRA track inspectors. While some of the comments were positive, there were also negative comments. The negative comments tended to focus on the perception that FRA inspectors are, under certain circumstances, not very helpful when it comes to explaining and interpreting the FRA regulations to railroad personnel. One comment also addressed the lack of uniformity of some enforcement policies between different FRA regions.

Based on the interview data, there does not appear to be common consensus on a recommended speed for inspections conducted from a hi-rail vehicle. Labor union officials advocate 20 mph for an effective inspection. Three of the six system-level officers interviewed said that their railroad does not have a recommended speed for hi-rail inspection; three indicated that they have a maximum inspection speed but did not provide an exact numerical value for this speed. Individual railroads typically prescribe a maximum hi-rail speed, for inspection or otherwise; a typical limit is 40 mph.

There was general agreement that inspectors have the tools they need to conduct inspections. Both labor union officials and railroad management indicated that visual inspection can find most of the track safety issues. RSA was one of the conditions that was reported as hard-to-find through a visual inspection.

There was general agreement that, given adequate time, the visual inspection process works and that automated systems are an essential tool for guiding and focusing the visual inspection process.

4.3 Outputs from Ideal Observer Model

FRA believes that there may be a correlation between speed of inspection and quality of inspection. Therefore, prior to conducting the survey, an ideal observer model was constructed for visual track inspection. The ideal observer model provides an upper limit on how well the best possible observer can perform by making optimal use of the information available from the stimulus. The purpose of the ideal observer model is to serve as a comparison to practices reported in the track inspector survey regarding speed at which visual track inspections are routinely performed. This section briefly discusses results of the ideal observer model. For a complete development of the ideal observer model, including derivations of the relevant equations, assumptions made during formulation, and limitations of the model, refer to Appendix H.

The plot in Figure 18 represents the output of the model assuming that 95-percent detection accuracy is acceptable and assuming the ideal observer is searching for 16 items simultaneously; based on the number of different defects that railroad track inspectors routinely look for, it is assumed that 16 objects is a reasonable number to use in the ideal observer model. The plot indicates that the speed at which an accurate detection is possible depends upon the size of the objects to be detected. In the plot, it is assumed that all 16 objects that the ideal observer is searching for are of the same size. For example, if the ideal observer is searching for 16 1.5-inch-sized objects and 95 percent detection accuracy is desired, then a maximum speed of 16.3 mph should be observed.

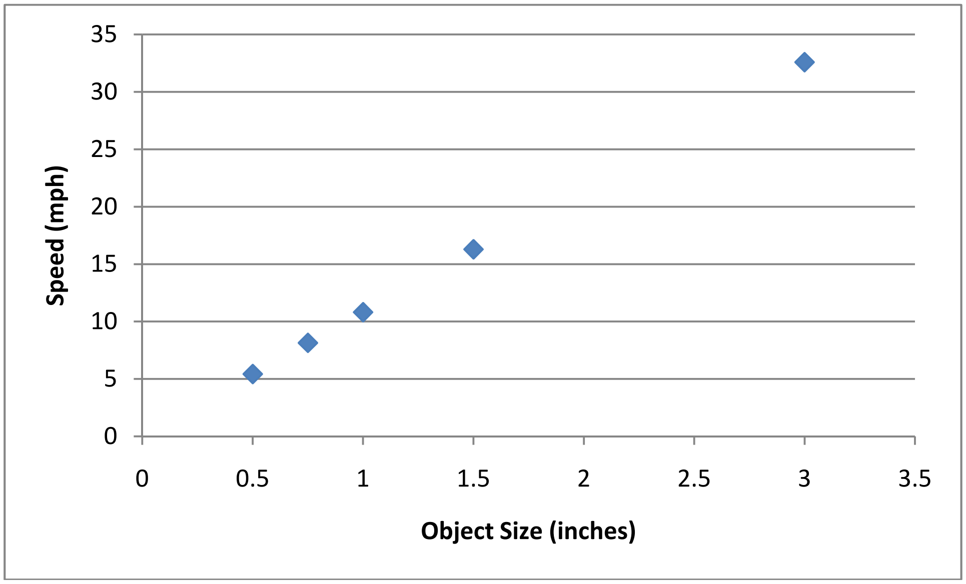

Figure 18. Ideal observer output for a 16 object search with 95-percent detection accuracy

The inspector survey indicates that speed of track inspection ranges from 5 mph to 30 mph depending on the type and condition of the track being inspected. The mean calculated speed for those primarily inspecting by hi-rail was 13.9 mph. These values appear to correspond well with the output of the ideal observer model. As discussed above, the ideal observer suggests an inspection speed of 16.3 mph if 16 variable 1.5-inch-sized objects are being sought. Track inspectors are searching for various size objects, many of which are much larger than 1.5 inches, such as fouled ballast and excessive wayside vegetation. Furthermore, inspectors use auditory as well as visual signals to detect defective track conditions. For example, loose joints, rail mismatch, or other variation in the running surface often create a distinct audible noise when the hi-rail vehicle moves over them. In conclusion, the ideal observer analysis, therefore, generally suggests that current inspection speeds are adequate.

4.4 Defects Found by FRA Track Inspectors

To supplement the track inspector survey, FRA track defect data was compiled in order to determine the prevalent track defects identified in the field by FRA inspectors. The data was obtained from each of the eight FRA regions for a 4-year period (2006–2009). The number and type of defects found by FRA inspectors may provide information on the effectiveness and quality of the current inspection process.

Figure 19 presents the results for each defect type arranged in descending order of percentage of the total number of defects identified. The data represents a total of 350,719 defects found and documented by FRA track inspectors between 2006 and 2009. The bars in Figure 19 are color-coded to denote whether the defective condition is considered "hard" (blue) or "soft" (orange) in terms of the relative objectivity of the determination that the defective condition exists (as discussed in Section 2.2 of this report).

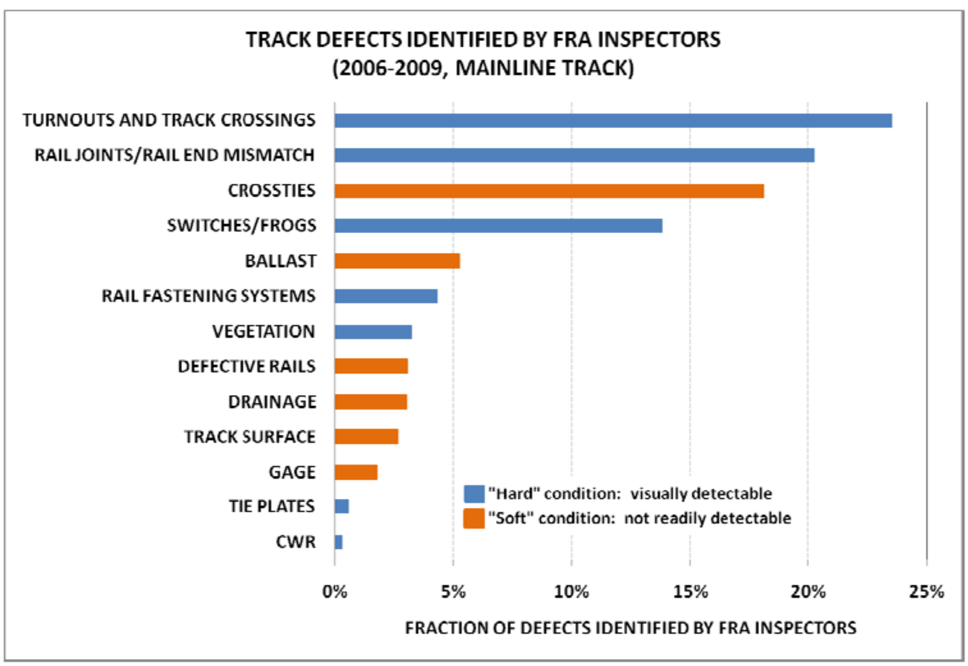

Figure 19. Track defects identified by FRA track inspectors (2006–2009)

Figure 19 clearly indicates that the predominant defects identified during this period were related to turnout, rail joint, and crosstie issues. Figure 20 shows the historical trends for these defects over the subject period and affirms that these conditions are the most frequently identified defects for each year. Each of these three defect types always account for more than 15 percent of the total number of track defects identified by FRA inspectors in a given year. Turnouts (and special trackwork generally) and rail joints are chronic problems for the railroad industry as these components are subjected to extreme loading from passing trains.

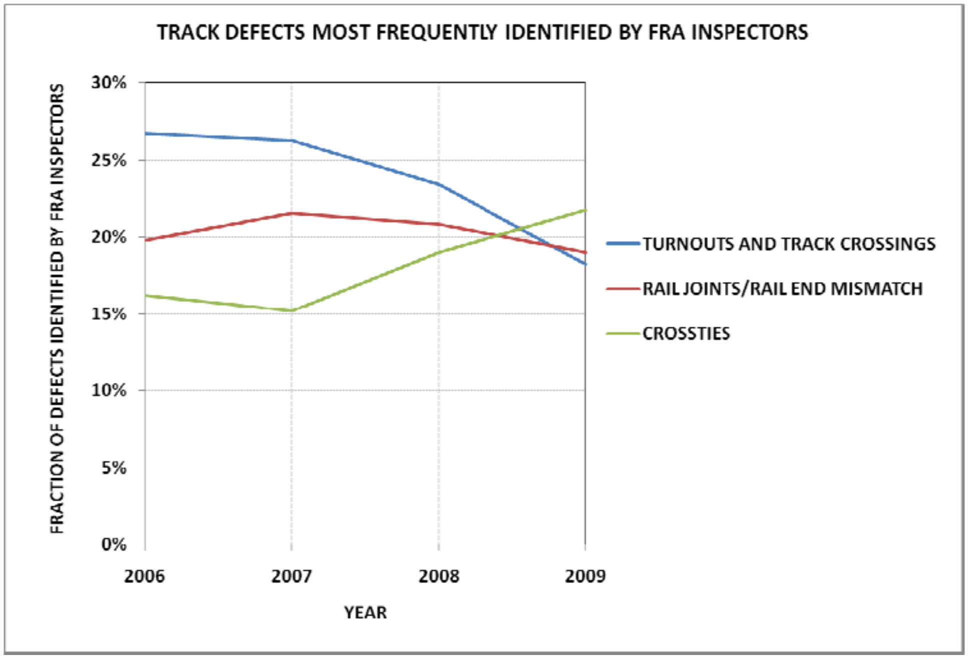

Figure 20. Historical trend of most common defects identified by FRA track inspectors

Turnouts allow trains to travel from one track to an adjacent track through a curve and a set of switches, and they are affected primarily by large lateral loads generated as the train negotiates the curve. When the loads become sufficiently large, the rail fastening system which keeps these components properly aligned can be overloaded and begin to fail. Degraded or weak fastening is the most frequent defective condition attributed to track turnouts and is considered to be "hard" implying that this condition is typically readily detectable by an inspector.

Rail joints are equally problematic for railroads as they represent a "weak link." Joints in track are necessary for many reasons (rail defect repair, electrical isolation of track sections for signaling purposes) and as such their deficiencies must be addressed. Wheel impact loads at the rail end gap in the center of the joint are the primary contributor to joint failure. Joint bars exhibit many failure modes including center cracks near the rail end gap, cracks emanating from bolt holes, as well as potentially more benign conditions such as missing or loose bolts. Bolt-hole cracks are the cause of the majority of derailments attributed to joint bar defects. In contrast, data collected by the FRA regarding results of on-foot inspections of joints in CWR under the requirements of Section 213.119 (as revised in 2006) indicate that a center-crack is the most common joint defect identified during such inspections. This disparity between condition and cause may suggest that bolt hole cracks are more difficult to detect visually. Nevertheless, joint defects are also considered "hard" or readily detectable conditions.

Crosstie defects are the third most frequently identified defect by FRA track inspectors. This is not especially surprising since crossties exist in substantially greater numbers in track (one tie every 20 inches or so) than either turnouts or rail joints. Acknowledging this fact, FRA regulations related to crossties essentially focus on prescribing the number of "effective" ties that must exist in any 39-foot track segment and certain parameters related to permissible tie degradation. Notwithstanding the prescriptive (discrete or "hard") aspects of the crosstie regulations, the determination whether a crosstie is defective is dependent upon an assessment of its "effectiveness" which, as described in Section 2.2 of this report, is a "soft" or more subjective evaluation.

Further examination of Figure 19 suggests that with the exception of crosstie defects, all other "soft" conditions are small in number. By definition, confirmation of the existence of these defects often depends on judgment or reliance on automated means. Acknowledging the time and effort required to confirm the presence of certain of these defects (such as track geometry defects) and the fact that railroad track inspectors and FRA track inspectors apply the same techniques or methods as part of the visual inspection process, detection of these conditions may be challenging.

5. Recommendations

The track inspector survey, along with the interviews conducted with labor union officials and various levels of railroad management, provides a snapshot of the current track inspection process. The data collected facilitates focusing on certain aspects of the track inspection process for further investigation for the purpose of identifying how the effectiveness of track inspectors can be improved. This section describes four issues for consideration as improvements to the track inspection process:

- Integration of visual and expanded automated inspections
- Track inspector training
- Speed of inspection
- Railroad operating practices and culture

5.1 Integration of Visual and Expanded Automated Inspections

The first issue under consideration is the expanded use of automated inspection systems in the track inspection process. From the tabulation of responses to the track inspector survey questions regarding the typical means by which track inspectors identify FRA defects (see Appendix C), it is clear that data from such systems is increasingly being used (and possibly relied upon) by track inspectors. The table in Appendix C shows that at least 30 percent of respondents use automated data to find track geometry-related defects.

Automated inspection techniques are described in Section 3.2 of this report and those required by FRA regulations are outlined in Section 3.4 and summarized in Table 2. Table 2 underscores the fact that automated track geometry measurements are required only for FRA track classes 7–9. Any other deployment of such systems by a railroad or track owner is elective.

Figure 19 presents all the defects identified nationwide by FRA track inspectors between 2006–2009. The findings suggest that, for this sample, the number of track geometry-related defects (track surface, gage) represents a small fraction. This can be construed to imply that either track geometry defects are relatively few in number generally, FRA inspectors rely on automated measurement systems for inspection of track geometry, or that FRA inspectors do not typically (due to the extent of territory for which they are responsible) invest the time required to make the numerous manual measurements necessary to confirm the existence of certain track geometry defects. If the latter is the case, it may also hold true for railroad track inspectors as well, especially when considering the fact that a majority (60 percent) of track inspectors indicated that pressure to complete inspections and limited track time were generally among the primary causes of adjustments to the speed at which they perform inspections.

It is also evident that the track inspectors performing visual inspections cannot readily or easily detect certain track defects. The two track defects for which this is true, according to the survey, are highlighted in green in the table in Appendix C; they include torch cut bolt holes and RSA of concrete ties. Torch cutting of bolt holes is now a prohibited practice according to 49 CFR §§ 213.121(g) and 213.351(f), although some may still exist in track. The detection of a torch cut bolt hole is practically impossible without disassembly of the joint. RSA is equally difficult to detect visually, given the physical location of the defect and the position in which the inspector must place himself in order to view the affected area of the tie.

Therefore, expanding the use of automated inspections already required by the TSS (such as TGMS inspections) would be beneficial in terms of improving inspection effectiveness by targeting inspection resources where needed, resulting in a corresponding safety improvement. If inspection burden can be lowered by supplementing the process with automated means, railroad track inspectors can more strategically apply limited track time and inspection and repair resources. FRA also believes that there could be significant safety benefits to using additional automated inspection systems not currently required by the TSS or which do not yet exist. Continued commitment to research and development efforts to identify and develop systems capable of detecting defects that are commonly missed by the visual inspection process (such as RSA) is essential.

5.2 Track Inspector Training

The second issue for consideration is training. Standardization of training was repeatedly identified as an issue by labor union officials. Furthermore, survey data indicates that the predominant form of initial track inspector training is on-the-job training; also, in the write-in portion of the survey, several inspectors commented that they would like to receive more formal training, rather than simply on-the-job training. FRA is aware of the general non-uniformity in track inspector training due to the excessive use of informal, on-the-job training. This non-uniformity may be due, in part, to the absence of specific FRA regulations or guidelines in this area. Historically, FRA has not played a direct role in the training and certification of industry track inspectors. Even presently, FRA does not envision being the sole authority to train and certify industry track inspectors. Rather, FRA will consider establishing formal guidelines and a skeleton curriculum that will establish minimum training requirements. These minimum training requirements will provide guidance to the railroads, as well as third-party trainers, and will help ensure uniformity in the track inspector training process.

Formal track inspection training guidelines to be proposed by FRA may involve the development of new regulations similar to those presently recommended by RSAC's RITF and Track Safety Standards Working Group for addressing rail integrity including minimum training requirements for operators of rail flaw detection equipment and a definition of a "qualified operator." The Working Group's recommended training requirements are presented in Appendix I in draft form and were accepted by the full RSAC body on September 23, 2010.

5.3 Speed of Inspection

The third issue is the speed of track inspection. There is generally no industry-standard operating speed for hi-rail vehicles used in track inspection. While labor union officials contend that 20 mph is reasonable, this may not be appropriate for certain track conditions for which detailed inspections are required. The speed at which track inspectors travel over their territories depends on many factors, including the age of the track, the amount of traffic it accommodates, and geographic conditions. If the establishment of such a speed limit were determined to be critical to improvement of the track inspection process, the formulation of the ideal observer outlined in Appendix H provides a sound analysis of the variables that come into play in human detection of various sized objects at different speeds. However, the empirical data and constants currently being used in the model can be thought of as generic in nature and certainly not specific to track inspection. Therefore, the speeds suggested by this model served as a quick reality check on the speeds reported by track inspectors and cannot be construed as optimized for the track inspection process. In order to gain the necessary empirical data on detectability of specific FRA defects both on foot and at different speeds in a hi-rail vehicle, it is necessary to conduct experiments on a test track with known defects. Only by doing this can the relationship between speed of inspection and detection accuracy be more conclusively determined. The setup and conduct of such experiments would require significant time and resources and this effort is deemed to lie outside the scope of this report. FRA believes that due to the vast number of variables (such as track condition, weather, and inspector experience) that affect an effective inspection speed, it may be counterproductive to set a maximum inspection speed. Rather than focus on maximum inspection speeds, FRA would prefer to focus more on how to achieve efficient and effective inspections.

5.4 Railroad Operating Practices and Culture

The final issue concerns railroad operating practices and safety culture. As the data and comments from the survey and interviews indicate, railroad operating practices often limit the amount of track time available to the track inspector. Specifically, in the survey data, it can be seen that three out of the top four reasons (namely time pressure to complete work, dispatcher decisions, and inadequate track time) for a track inspector's change in speed of inspection are factors that, at least ideally, can be alleviated by changes in railroads' operating practices. The comments from track inspectors, track supervisors, and labor union officials tended to support these survey data and point to the allegation that railroad operating practices in many cases limit track inspectors' track time. Track inspectors also reported that over time they have been assigned increasing amounts of non-inspection duties that limit the time they have available for track inspections. In addition, the inspector's ability to carry out safety-critical duties is often compromised by an industry safety culture that discourages the inspector from issuing slow orders. In these instances, safety is compromised in the interest of service goals.

The implementation of a safety reporting system is one means to address these issues and to begin to change the safety culture in the maintenance-of-way department. Safety reporting systems provide a confidential, non-punitive, and anonymous way for employees to report near-misses and other safety risks, such as management pressure to either ignore or downplay the severity of identified track defects. A report review team consisting of representatives from labor, management, and the regulator would meet periodically to review the reports and recommend solutions. The Aviation Safety Action Program for airline pilots and the Air Traffic Safety Action Program for Federal Aviation Administration air traffic personnel have been successful in identifying and resolving issues that otherwise might not have come to the attention of transportation industry management. The Confidential Close Call Reporting System (C3RS), a pilot implementation of a safety reporting system for the railroad industry, is experiencing similar successes, but to date, only train and engine service employees have participated.

Because these systems require trust and cooperation among the stakeholder groups, ultimately they result in a shift in the safety culture of the organization.

All four of these issues (including additional automated inspections, track inspector training standardization, speed of inspection, and railroad operating practices) will be formally considered and addressed through the RSAC process.

Appendix A.
Section 403 of the Rail Safety Improvement Act of 2008 (Public Law 110-432, Div. A.)

SEC. 403. TRACK INSPECTION TIME STUDY.

(a) STUDY.—Not later than 2 years after the date of enactment of this Act, the Secretary shall transmit to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report containing the results of a study to determine whether—

(1) the required intervals of track inspections for each class of track should be amended;

(2) track remedial action requirements should be amended;

(3) different track inspection and repair priorities or methods should be required; and

(4) the speed at which railroad track inspection vehicles operate and the scope of the territory they generally cover allow for proper inspection of the track and whether such speed and appropriate scope should be regulated by the Secretary.

(b) CONSIDERATIONS.—In conducting the study the Secretary shall consider—

(1) the most current rail flaw, rail defect growth, rail fatigue, and other relevant track- or rail-related research and studies;

(2) the availability and feasibility of developing and implementing new or novel rail inspection technology for routine track inspections;

(3) information from National Transportation Safety Board or Federal Railroad Administration accident investigations where track defects were the cause or a contributing cause; and

(4) other relevant information, as determined by the Secretary.

(c) UPDATE OF REGULATIONS.—Not later than 2 years after the completion of the study required by subsection (a), the Secretary shall prescribe regulations based on the results of the study conducted under subsection (a).

(d) CONCRETE CROSS TIES.—Not later than 18 months after the date of enactment of this Act, the Secretary shall promulgate regulations for concrete cross ties. In developing the regulations for class 1 through 5 track, the Secretary may address, as appropriate—

(1) limits for rail seat abrasion;

(2) concrete cross tie pad wear limits;

(3) missing or broken rail fasteners;

(4) loss of appropriate toeload pressure;

(5) improper fastener configurations; and

(6) excessive lateral rail movement.

Appendix B.
Track Inspector Survey

OMB No. 2130-0588

ID Number:

Track Inspector Survey

Please return this survey by May 24, 2010 in the enclosed envelope.

If you have questions, please contact:
Amanda DiFiore
781.684.3978
amanda.difiore@qinetiq-na.com

Judy Gertler
781.684.4270
judy.gertler@qinetiq-na.com

The Federal Railroad Administration (FRA) is conducting a study of track inspection time. The purpose of the study is to develop an understanding of the current industry practices as required by the Rail Safety Improvement Act of 2008. The study results will inform possible future FRA policy and regulatory actions, and, in general, will contribute to overall railroad operational safety.

The data collected from this study will be used primarily for statistical purposes, and is authorized by law (49 U.S.C. 20901). Your participation in this study is completely voluntary. Your personal information will be kept private to the extent permitted by law, and will not be disclosed to anyone other than employees and contractors who work on this study.

Public reporting burden for this information collection is estimated to average 30 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Please note that an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The OMB control number for this information collection is OMB No. 2130-0588 and the expiration date is April 30, 2013.

Instructions

Fill in the bubbles to indicate your answer.
Use black or blue ballpoint pen or a Number 2 pencil.

Please fill in marks like this: ● ○ ○

Not like this: ⊗ ✓ ●

Form FRA F6180.136 (07/09)

Your Job

How long have you worked as a track inspector? ________ years

How long have you worked on your assigned territory? ________ years

How were you initially trained to perform track inspections? (mark all that apply)

- ○ company training program
- ○ on-the-job training
- ○ other

What types of subsequent training have you had for your current position? Indicate how often you have had the training.

	Never	Less than every other year	Every other year	Every year	More frequently
on-the-job training	○	○	○	○	○
FRA track standards training	○	○	○	○	○
FRA safety standards training (e.g., roadway worker protection)	○	○	○	○	○
other track inspection related training (please specify below)	○	○	○	○	○

Specify other track inspection related training if applicable

____

____

Do you have job briefings? ○ Yes ○ No (Skip to **Your Work Day**)

If you have job briefings, please answer the following:
How are your job briefings conducted?

○ in-person ○ on the phone ○ both

How often do you have job briefings?

- ○ daily
- ○ more than once a day
- ○ other (Please specify): ________________

Which of the following are included in your job briefings? (mark all that apply)

- ○ slow orders on territory
- ○ recent derailments
- ○ results of special inspections
- ○ spot maintenance
- ○ specialized equipment movement (e.g., rail flaw detection car)
- ○ recent accidents
- ○ results of track geometry inspections
- ○ rough ride reports
- ○ mechanized maintenance
- ○ other (Please specify): ________________

Your Work Day

Scheduled length of your work day: ________ hours

In the past month, how many days have you worked longer than the scheduled length of your workday?

O none   O 1 - 5   O 6 - 10   O 11 - 15   O >15

In the past month, how many times did you work on a rest day?

O none   O 1   O 2   O 3   O 4   O 5   O >5

On a typical day in the past month, how much time did you spend doing each of the following:

	Time (minutes)								
	0-15	>15-30	>30-45	>45-60	>60-75	>75-90	>90-105	>105-120	>120
Travel (from reporting point to start of inspection)	O	O	O	O	O	O	O	O	O
Non-inspection duties	O	O	O	O	O	O	O	O	O
Job briefings	O	O	O	O	O	O	O	O	O
Waiting for track time	O	O	O	O	O	O	O	O	O
Reporting inspection results	O	O	O	O	O	O	O	O	O
Lunch and breaks	O	O	O	O	O	O	O	O	O

	Time (hours)									
	1	2	3	4	5	6	7	8	9	10
Inspection	O	O	O	O	O	O	O	O	O	O
Repair	O	O	O	O	O	O	O	O	O	O

On a typical day, how many miles of *track* do you inspect? ________miles

(If you inspect 10 miles of double track, write 20; if 10 miles of triple track, write 30, etc.)

Which conditions cause you to adjust the speed of your inspection? (mark all that apply)

- O time pressure to complete work
- O weather
- O interlocks
- O other (Please specify): ______________________________
- O inadequate track time
- O highway crossings
- O dispatcher decisions

2

Your Territory

Number of Track Miles - **Mainline** ____________

Number of Track Miles - **Siding** ____________

Number of Sites - **Industry Track** ____________

Number of Sites - **Yard Track** ____________

Class of main track (mark all that apply):

- O Excepted
- O 1
- O 2
- O 3
- O 4
- O 5
- O 6 and above

Territory characteristics (mark all that apply):

- O single track
- O double track
- O more than double track
- O CWR
- O desert terrain
- O mountainous terrain
- O concrete ties
- O urban area
- O tunnels
- O bridges
- O highway crossings
- O other (Please specify): ____________________________

My territory consists of:

	Mostly	Some	Not much	Maximum curvature
curved track	O	O	O	____________
straight/tangent track	O	O	O	n/a

Inspection Procedure

Using the following scale, rate how often you use the following methods to inspect your territory:

	Only method I use	Use most of the time	Use some of the time	Rarely use	Never use
by high-rail	O	O	O	O	O
on foot	O	O	O	O	O
inspect by other method (please specify below)	O	O	O	O	O

Specify other inspection method if used: ____________________________

3

If by hi-rail, at what speed do you inspect:

Track Characteristic	**Speed (mph)**
straight/tangent CWR	________
straight/tangent jointed track	________
control points	________
curves	________

I conduct inspections (mark one)

- ○ alone
- ○ mostly alone
- ○ with another inspector
- ○ mostly with another inspector

In the past year, how frequently did your roadmaster/track supervisor go over your territory with you?

○ monthly ○ quarterly ○ less frequently

What prompts you to conduct a special inspection? (mark all that apply)

- ○ weather/climate
- ○ report of dragging equipment
- ○ signal malfunction
- ○ report from automated inspection
- ○ short-term change in traffic pattern
- ○ train going into emergency
- ○ derailment
- ○ locomotive engineers' feedback
- ○ other (Please specify): ____________________

How many times in the last month did you conduct a special inspection?

○ never ○ 1-5 ○ 6-10 ○ 11-15 ○ 16-20 ○ >20

In the past month, how many hours did you spend on special inspections? ________ hours

Which of the following do you have with you when inspecting? (mark all that apply)

- ○ calipers
- ○ clip inserter/remover
- ○ elastic clips
- ○ tape measure
- ○ stringline
- ○ spikes
- ○ set of joint bars
- ○ PTLF
- ○ gage bar
- ○ bolts
- ○ spike maul
- ○ level board
- ○ rail thermometer
- ○ other (Please specify): ____________________

I do not have the following with me when inspecting, but would find it useful:

____

____

4

How do you commonly detect each condition?

Track Condition	Visual - On Foot	Visual - Hi-rail	Results from automated inspection	Not readily detectable	Not applicable in my territory
Geometry					
Gage dimension less than/greater than allowable	O	O	O	O	O
Alinement deviation exceeds allowable	O	O	O	O	O
Maximum crosslevel exceeds allowable	O	O	O	O	O
Runoff at end of raise exceeds allowable	O	O	O	O	O
Deviation from uniform profile on either rail exceeds allowable	O	O	O	O	O
Difference in crosslevel (warp) exceeds allowable	O	O	O	O	O
Reverse elevation on curve exceeds allowable	O	O	O	O	O
Ballast					
Insufficient ballast	O	O	O	O	O
Fouled ballast	O	O	O	O	O
Ties					
Ineffective/defective ties	O	O	O	O	O
Rail seat abrasion	O	O	O	O	O
Track constructed without crossties does not effectively support track structure	O	O	O	O	O
Rail/joints					
Broken rail	O	O	O	O	O
Worn rail	O	O	O	O	O
Rail-end mismatch	O	O	O	O	O
Cracked or broken joint bar	O	O	O	O	O
Insuffient number of joint bolts	O	O	O	O	O
Loose/worn joint bolts	O	O	O	O	O
Torch-cut or burned-bolt hole in rail	O	O	O	O	O

5

How do you commonly detect each condition?

Track Condition	Visual - On Foot	Visual - Hi-rail	Results from automated inspection	Not readily detectable	Not applicable in my territory
Switches					
Stock rail/switch point not seated or functioning as intended	O	O	O	O	O
Loose, worn, or missing switch components	O	O	O	O	O
Fasteners/anchors					
Insufficient/ineffective fasteners	O	O	O	O	O
Insufficient anchors to restrain rail movement at turnouts or CWR	O	O	O	O	O
Frogs					
Insufficient flangeway depth/width	O	O	O	O	O
Worn or defective frog/frog components	O	O	O	O	O
Miscellaneous					
Heat kinks	O	O	O	O	O
Right-of-way obstructions	O	O	O	O	O
Object between base of rail and the bearing surface of the tie plate causing concentrated load	O	O	O	O	O
Insufficient/defective tie plates	O	O	O	O	O
Missing or damaged signage	O	O	O	O	O
Track washouts	O	O	O	O	O
Poor drainage/pumping ties	O	O	O	O	O
Excessive vegetation	O	O	O	O	O
Defective derail condition(s)	O	O	O	O	O

Which of the following repairs do you make while inspecting? (mark all that apply)

	Tie Plates	Missing Fasteners	Missing Bolts	Broken Joint Bars	Gauge Adjustment	Spot Surfacing
alone?	O	O	O	O	O	O
with another inspector?	O	O	O	O	O	O

How do you report the results of your inspection?

	Always	Mostly	Sometimes	Never
paper reporting	O	O	O	O
electronic reporting	O	O	O	O

Which type of reporting do you prefer? O paper O electronic

What other types of inspections are done on your territory? (mark all that apply)

O ultrasonic rail flaw detection
O gage restraint measurements
O none
O other (Please specify): ______________________________
O track geometry measurements
O vehicle track interaction

Rate the usefulness of the following technologies:

	Don't know	Not useful at all	Somewhat useful	Useful	Very Useful	Essential
ultrasonic rail flaw detection	O	O	O	O	O	O
track geometry measurements	O	O	O	O	O	O
gage restraint measurements	O	O	O	O	O	O
vehicle track interaction	O	O	O	O	O	O

Please comment on any other aspect of the inspection process that you would like the FRA to consider in preparing its Report to Congress. (attach additional sheets, if necessary)

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Appendix C.
Detection of Track Defects Through Visual Inspection[1],[2]

	Visual – On foot	Visual – Hi-rail	Data from Automated Inspection	Not Readily Detectable	Not Applicable
Gage dimension less than/greater than allowable	78.48%	36.29%	37.97%	1.69%	0.00%
Alinement deviation exceeds allowable	51.48%	65.82%	33.33%	1.27%	0.84%
Maximum crosslevel exceeds allowable	64.98%	54.43%	35.44%	0.42%	0.00%
Runoff at end of raise exceeds allowable	58.65%	52.32%	30.80%	2.95%	1.69%
Deviation from uniform profile on either rail exceeds allowable	61.60%	55.27%	33.33%	1.69%	0.84%
Difference in crosslevel (warp) exceeds allowable	67.51%	49.79%	37.97%	0.84%	0.00%
Reverse elevation on curve exceeds allowable	63.71%	51.05%	33.76%	0.42%	1.69%
Insufficient ballast	29.11%	85.65%	1.27%	0.00%	1.27%
Fouled ballast	39.66%	80.17%	1.27%	0.42%	1.27%
Ineffective/defective ties	83.97%	42.19%	2.11%	0.42%	0.42%
Rail seat abrasion	73.00%	14.77%	3.38%	8.44%	8.86%
Track constructed without crossties does not effectively support track structure	60.76%	28.27%	2.11%	2.11%	19.83%
Broken rail	56.96%	75.11%	15.61%	0.00%	0.00%
Worn rail	71.31%	44.30%	16.03%	1.69%	0.42%
Rail-end mismatch	75.53%	52.32%	0.42%	0.42%	0.00%
Cracked or broken joint bar	88.61%	37.55%	1.27%	0.00%	0.00%

[1] Rows highlighted in red represent defects in which at least 30 percent of respondents indicated that they use automated inspection data to assist them in locating the defective condition.
[2] Rows highlighted in green represent defects in which at least 5 percent of the respondents indicated that they cannot readily detect the condition during a visual inspection.

	Visual – On foot	Visual – Hi-rail	Data from Automated Inspection	Not Readily Detectable	Not Applicable
Insufficient number of joint bolts	57.38%	76.79%	0.42%	0.00%	0.00%
Loose/worn joint bolts	82.28%	41.77%	0.42%	0.00%	0.84%
Torch-cut or burned-bolt hole in rail	62.87%	5.91%	3.80%	8.02%	26.58%
Stock rail/switch point not seated or functioning as intended	98.31%	13.50%	0.42%	0.00%	0.42%
Loose, worn, or missing switch components	97.05%	18.57%	0.00%	0.00%	0.00%
Insufficient/ineffective fasteners	77.64%	40.93%	0.00%	0.00%	0.42%
Insufficient anchors to restrain rail movement at turnouts or CWR	83.97%	35.44%	0.00%	0.00%	0.42%
Insufficient flangeway depth/width	97.05%	9.28%	0.42%	0.00%	0.84%
Worn or defective frog/frog components	94.51%	22.78%	0.84%	0.00%	0.00%
Heat kinks	28.27%	88.19%	0.42%	0.42%	1.69%
Right-of-way obstructions	24.47%	88.61%	0.42%	0.42%	0.84%
Object between base of rail and the bearing surface of the tie plate causing concentrated load	87.34%	20.25%	0.42%	2.95%	1.69%
Insufficient/defective tie plates	80.17%	34.18%	0.84%	1.69%	1.27%
Missing or damaged signage	22.78%	87.76%	0.42%	0.00%	1.27%
Track washouts	37.55%	83.54%	0.42%	0.84%	3.38%
Poor drainage/pumping ties	54.85%	77.64%	1.27%	0.42%	0.42%
Excessive vegetation	24.05%	89.03%	0.00%	0.42%	0.84%
Defective derail condition(s)	78.06%	32.91%	11.39%	1.27%	0.42%

Appendix D.
Results of Interviews with Labor Union Officials

Number of interviewees	• 5 general or vice chairmen • 1 director of education and safety

What types of inspection-related training does your membership receive from the railroad?
The union officials confirmed that, in general, there is RWP training every year and some type of track standards training every other year. Initial training may vary across railroads or even on subdivisions within a railroad. Specific recommendations of union officials included:

- Roadmasters are in need of more training, not the inspectors. Railroads have been hiring people out of college to be roadmasters, and they know nothing about the railroad or track inspection. Inspectors need someone, outside of the carrier, to call if there are questions. This could be an independent person who knows how FRA would react to a given situation. This needs to be a resource person who is not a regulator.

- Training should be more standardized and there should be a schedule for retraining. Training should also include practical application, not just classroom activities. Mentoring should be a part of the training process. This would involve coupling an experienced inspector with a trainee for a period of time. There may be value in having FRA conduct the initial training.

What factors hinder performing quality inspections?
Note: Numbers in parenthesis in this Appendix indicate the number of comments regarding this factor over the total number of labor union officials interviewed.

- Frequency of trains in this commuter operation makes it difficult to work when the inspector constantly has to watch for approaching trains while doing the inspection. (1/6)
- Pressure to do more work in less time. One general chairman reported that there is pressure not to do overtime. (3/6)
- Increasing amount of non-inspection duties (e.g., piloting a work train across the territory). (2/6)
- Lack of support forces for repairs. (2/6)
- Availability of track and time. (2/6)
- Number of inspectors in the vehicle (should have two). (2/6)
- Pressure to avoid a slow order. (2/6)

What equipment would aid the track inspector in safely performing inspections?

Overall, union officials thought the inspectors have the tools they need but they did offer a few suggestions:

- Old style hi-railer without nose gives a better view of the track.
- Device in hi-railer to detect elevation difference between rails would be helpful. Division engineers have these.

How could the track inspection process be changed?

Overall, union officials feel that, given enough time, the process works. One general chairman thought that bringing back the Track Inspection Playbook, that one of the Class I railroads used in the early 1990s, would be a big help to inspectors.

What factors influence the speed at which the hi-railer operates during inspections?

There is general agreement on the relevant factors, which are:

- Availability of track and time, which depends upon the frequency of trains. (4)
- Length of the territory given the limited time; pressure to complete inspection on time.
- Whether or not the inspector is inspecting for and reporting defects, or inspecting for and repairing defects.
- Type of rail – slower for jointed rail than CWR. (2)
- Number of joints that must be inspected.
- Number of inspectors in the vehicle. (Lone inspector goes slower.)
- Condition of the track. (2)
- Speed varies depending upon what the inspector is looking for/at.
- Inspectors looking only for heat kinks and, conversely, cold weather pull-aparts could average 30 mph if straight track.
- Speed set by carrier. (2)
- Pressure to complete inspection on time.

BMWED advocates 20 mph maximum speed for an effective inspection.

What types of automated inspections do your members find useful? In what way are they useful?
There was general agreement on the value of automated inspections as follows:

Type of inspection	**Responses**
Ultrasonic rail flaw detection	Find internal defects before visible.
GRMS	Surrogate for finding rail seat abrasion. Best used as adjunct to visual inspection. Could be adapted to measure rail seat abrasion on concrete ties (due to moisture).
PTLF	Not a lot of benefit to the inspector. Visual inspection usually adequate. Provides non-subjective measurement.
TGMS	Guides inspection. Track inspector must get report and be trained on interpretation.
VTI	Not really a track inspector's concern. Inspector looks at track only.

Which track conditions are "not readily detectable" by the visual track inspection process?

- Rail seat abrasion – track geometry car and GRMS could detect.
- Loose/worn joint bars – from hi-rail can hear it, on foot more likely to detect.
- Torch cut bolt hole – can only see it if remove joint bar.
- Insufficient anchors – inability to measure stressors on the rail.

What track inspection issues do your members bring to your attention?

Each union official interviewed offered unique issues, except for length of territory where three people commented.

- Length of territory: one comment about territory size being too large; two comments that territory size was appropriate.
- Railroad only responds to automated inspection, not what the inspector says.
- Tie conditions are corrected only to get them to hold gage.
- Surface defects aren't corrected.
- Lack of repair staff is the biggest issue.
- Lack of track time.
- Management pressure; too much work pressure.

- Main issue is criticism inspectors receive for doing their job. Track inspectors do not receive the support for doing a good job.
- Upper management views track workers at side of tracks from passing train and assumes they are not working. Then, word comes from management that productivity is not adequate and there is pressure to do more.

Do you feel that the railroad has an adequate number of inspectors to comply with current FRA requirements? On what basis do you make that determination?

Two union officials responded "yes"; two responded "no"; and there was no response from one. Open inspector positions and difficulty covering vacations or other days off were offered as evidence of inadequate inspectors.

What changes, if any, would you recommend in current FRA track inspection requirements?

- FRA granted the Southeastern Pennsylvania Transportation Authority (SEPTA) a waiver regarding the twice-a-week inspection. This general chairman recommends removing the waiver. This would result in track being maintained to a higher standard. In addition, it would allow the inspectors to be responsible for two different sections of track, one inspected on Monday and Thursday and the other on Tuesday and Friday; they would develop familiarity with and "ownership" of that track, which would result in higher quality inspections.
- Require a minimum of two people in the hi-railer used in the inspection. Because more repairs could be done than with a single person, there would be less speed restrictions. The second person, a helper, would learn the job as well as assist with repairs.
- Give documentation to FRA, along with the inspection report, as to what the inspector did on a given day.
- In inclement weather (heat/cold), put two inspectors together for safety.
- Require two inspectors in hi-rail vehicle.
- Standardize the training for inspectors.
- Implement a maximum inspection speed for the hi-railer.
- Implement a maximum inspection speed.
- Put track inspectors under a track inspection supervisor who does not have other responsibilities.
- Current supervisors have competing goals that cause the quality of inspections to suffer. This is primarily due to a lack of local forces for doing repairs. The problem has evolved over time.

Are there any other aspects of the inspection process that you would like to comment on for FRA consideration in preparing its Report to Congress?

- The people who do these inspections are knowledgeable. Given adequate time, they will do a quality job.
- Inspectors are under more pressure to get inspections done in a timely fashion. If the inspector issues a speed restriction, the inspector will likely take "heat" from the supervisor, who in turn is getting pressure from above. The inspector is put on the defensive. The inspector must sign the inspection report, not the supervisor. If the inspector, against his better judgment, does not issue the speed restriction and there is a problem, the inspector is responsible.
- The inspector's job has gone from just doing inspection to inspection, plus remedial repairs, to one where the inspector is spending considerable time on non-inspection duties. If repair takes more than 30 minutes, repair should be done by repair force not the inspector.
- The current process works. FRA should tighten up on compliance to make sure that the railroad makes the needed repairs and complies with time requirements for those repairs.
- FRA should consider the results of the BMWED-distributed survey along with the results of these interviews of labor union officials in preparing its report.

Appendix E.
Results of Interviews with Roadmasters/Track Supervisors

Number of Interviewees	12

How long have you been a track supervisor?

Range	12 to 35 years
Mean	25.3 years
Median	26.0 years
Standard deviation	7.1 years

Did you work as a track inspector prior to becoming a supervisor? If so, how long?

Previous track inspection experience	5/12
Range	0.3 to 15 years
Mean	2.9 years
Median	3.0 years
Standard deviation	6.1 years

How many track inspectors do you supervise?

Range	1 to 6 track inspectors
Mean	2.9
Median	3.0
Standard deviation	1.4

On a typical day, how many hours do you work?

Range	9 to 13 hours
Mean	10.9 hours
Median	10.5 hours
Standard deviation	0.2 hours

On a typical day, how many hours do you spend on inspection issues?

Range	1 to 4 hours
Mean	1.9 hours
Median	2.0 hours
Standard deviation	1.1 hours

What types of training do your inspectors have that is specific to track inspection?

On-the-job:

More frequently than annually	10/12
Annually	2/12

FRA track standards:

Annually	8/12
Biennially	3/12
Less than biennially	1/12

FRA safety standards:

Annually	10/12
More frequently than annually	2/12

Other training:

Monthly ride along	4/12
Track inspection training every other year or every 3 years	2/12
Operating rules, every other year	1/12
Foreman refresher, every 3 years	1/12

What additional training is necessary for track inspectors?

None	6/12
More field training	1/12
Proper measurement training	1/12

How do you assure the proficiency of your track inspectors?
Review daily reports and conduct monthly ride along/co-inspection.

What action do you take to improve a track inspector's performance if it is unacceptable?
If an inspector's performance or skills are lacking or unacceptable, track supervisors will initially attempt to improve the inspector's performance with individualized on-the-job training. If that proves insufficient, the supervisor may prescribe further formal training, possibly implement official disciplinary/citation actions, and finally, in extreme cases, resort to removing that inspector from service.

How do you conduct job briefings with your inspectors?

In-person	11/12
Phone	7/12
Other: email	1/12

What topics are covered in the daily job briefings?

Slow orders on territory	12/12
Recent derailments	12/12
Results of special inspections	12/12
Results of track geometry inspections	12/12
Spot maintenance	11/12
Specialized equipment movement	11/12
Recent accidents	11/12
Mechanized maintenance	10/12
Rough ride reports	9/12
Other information included in job briefings*	5/12

* Other information included in job briefings:
- Inspection standards
- Recent injuries/safety concerns
- Upcoming projects
- Weather
- Rider complaints
- Previous shift's work

What criteria do you use to establish inspection territories?
The following items were mentioned:

- Track miles
- Number of switches and yards
- Million gross ton miles (MGT)
- Type of terrain
- Class of track

On a typical day, how many miles of mainline track do your inspectors cover in total? (If an inspector inspects double track, multiply miles of track by 2; if triple track, multiply by 3, etc.)

Range	25 to 110 miles
Mean	58.9 miles
Median	50.5 miles
Standard deviation	24.5 miles

What classes of main track do the territories of your inspectors include?

Class 1	7/12
Class 2	7/12
Class 3	9/12
Class 4	11/12
Class 5	4/12
Class 6	1/12
Class 7	0/12
Class 8	0/12
Class 9	0/12
Excepted Track	0/12

Do you feel that you have an adequate number of inspectors on your division?

Yes	10/12
No	2/12

How did you make that determination?
Most of the respondents based their assessment on the fact that their inspectors are able to cover the required territory in the allocated time and that no overtime is regularly required to inspect their territory.

Which of the following characterize the territories of your inspectors?

Single track	11/12
CWR	12/12
Concrete ties	4/12
Bridges	12/12
Industry track	12/12
Double track	10/12
Desert terrain	2/12
Urban area	8/12
Highway crossings	11/12
More than double track	3/12
Mountainous terrain	3/12
Tunnels	2/12
Yard	12/12
Other territory characteristics*	

* Other territory characteristics:
- Curves 4/12
- Rivers 4/12
- Flash floods 1/12
- Y-tracks 1/12

What characteristics of your territory create challenges for the track inspection process?
The most common responses were:
- Curves cause gauge measurement problems and can present greater safety risks
- Lack of track time due to high traffic
- Inclement weather

What territory characteristics trigger special inspections?

Extreme heat	12/12
Extreme cold	12/12
Desert terrain	1/12
Mountainous terrain	1/12
Other*	

* Other:
- Flash floods/excessive rain 12/12
- Fires 1/12
- Snow 1/12
- High winds 3/12
- Tornados 2/12
- Accidents/collisions 1/12
- Vandalism/trespassers 2/12

How are inspectors assigned to a specific territory?

Union bidding/seniority	8/12
Company selection/appointment	4/12

How often do you inspect with each of your track inspectors?

Monthly	11/12
Quarterly	1/12

Does your railroad inspect more frequently than FRA regulations require?

Yes	7/12
No	5/12

Examples are:
- Double the FRA requirements
- Yards are inspected once a week
- Mainline track is inspected daily compared to FRA's once a week requirement
- Mainline inspection four times a week

The two main reasons offered for greater inspection frequency are to maintain a higher level of safety and to avoid any operational downtime. Higher inspection frequencies are very common on key routes and routes that carry passengers or hazmat.

Does your railroad inspect to FRA minimum safety standards or are your standards more stringent?

Standards more stringent	7/12
FRA minimum standards	3/12
Unsure	2/12

Examples are:

- Class 1 track: Gauge tolerance is 57¾ inches vs. 58 inches for FRA
- Maintain all track to Class 5 standards or higher

What conditions would you <u>not</u> expect a track inspector working alone to fix?
(Note: Many of the respondents stated that the track inspectors might repair any of the below defects; it depends on the extent and number of defects.)

Tie plate issues	2/12
Broken joint bars	3/12
Missing fasteners	1/12
Gage adjustment	9/12
Missing bolts	0/12
Spot surfacing	10/12
Other conditions not fixed alone	6/12

Under what circumstances would you assign a single inspector to a territory? What circumstances warrant a two-person inspection team? What benefits are there to a single inspector? Two inspectors working as a team?
All, but one, of the interviewed railroads assign single inspectors for routine inspections. One railroad always has two inspectors per inspection team. They state that the reason for having one inspector is cost effectiveness and scheduling flexibility. However, the supervisors will assign more than one inspector to situations where safety is a concern–for example, inclement weather, dangerous localities, some special inspections, blind curves, and night patrols. Additionally, some of the supervisors responded that they assign two inspectors to yard and triple track inspections.

How do your inspectors report the results of their work?
Reporting is transitioning to electronic systems from paper-based systems. Verbal reports are frequently given on possible upcoming issues or "points of concern."

	Always	**Mostly**	**Sometimes**	**Never**
Paper Reporting	3	1	2	6
Electronic	10	0	1	1
Other*	0	1	5	6

*Other reporting methods include:

- Verbally, either in-person or on the phone
- Email

How could the reporting process be improved?

Works fine as is	5/12
Communication between defect reporting systems and repair/maintenance tracking systems	1/12
Standardizing methods for location identification	1/12

What additional equipment would you provide to your inspectors if cost were not a consideration?

Nothing else needed	3/12
Handheld computer/PDA for data entry	2/12
GPS for hi-rail	1/12
Temperature indicator on rear-view mirror	1/12
Mount laptop in hi-rail	1/12
Electronic gauge monitor built into the truck to monitor the gauge as the hi-rail rolls over track	2/12
Larger crews / Separate repair crew	2/12
Small hydraulic pump/circuit to drive hydraulic tools, especially have an impact wrench	1/12
Laser for checking surface alignment or digital self calibrating level board	2/12

How frequently do your inspectors work overtime to complete routine inspections? What causes the need for overtime? (e.g., waiting for track time, assignment to non-inspection duties, short-staffed)
Five out of 12 respondents stated that their inspectors work overtime at least twice a week. Common causes include lack of track availability and inclement weather conditions.

What types of automated inspections occur on your division? How frequently?

Type of inspection (# using)	**Responses**
Ultrasonic rail flaw detection (12)	There is considerable variation in frequency from once a month to twice a year.
GRMS (9)	Frequency varies from 4 times a year to once a year. All the respondents found GRMS to be very useful.
TGMS (11)	Respondents indicated that they use TGMS between 26 times a year to twice a year. They found TGMS to be very useful.
VTI (8)	Sporadic, based on when a vehicle equipped with VTI comes through their territory. All respondents found VTI to be useful.

Are there any other inspections that you would find helpful?

None	11/12
A machine to check for "tight rail"	1/12

Are there any aspects of the inspection process that you would like to comment on for FRA consideration in preparing its Report to Congress?

- One respondent raised the concern that railroads are causing a "time bomb on ties" because they ignore bad ties if the rail surface quality is acceptable. This is leading to a potentially dangerous situation in which high-traffic rail is supported by decayed or damaged ties.
- On certain railroads, the inspector who reports a fault is assigned the responsibility for repairing it or having it repaired. This potentially deters already overworked inspectors from reporting faults; the more faults they report, the more work they give themselves.
- One respondent stated that remote track authority, instead of increasing inspector safety, is leading to potentially hazardous situations. Track inspectors may lose wireless service on their laptops and are unable to determine if they still have track authority in that section. Additionally, during track release, the computer is not responsive enough for them to obtain feedback with enough of a safety margin. There have been instances of the system releasing track when the inspector is still in the danger zone.
- The supervisors also commented on inconsistency between FRA inspectors, i.e., different FRA inspectors interpret the same regulation differently. It would be beneficial if FRA defined the regulations or standards better, with the use of detailed pictures to supplement the word descriptions.
- Similarly, FRA inspectors need to be a "Dr. of the railroad" and understand why and how the regulations and standards are defined. FRA inspectors should not respond to inquiries with, "That's just the way it is."
- Certain respondents stated that they have no problems with FRA, and like openness and accessibility of FRA officials for discussion or help. However, other respondents stated that they find FRA to be very intimidating and that FRA officials do not treat them with dignity and respect. They stated that FRA can be very rude, especially the individuals higher in the hierarchy. It was also mentioned that people who leave railroads as disgruntled employees are hired at FRA.
- One supervisor highlighted that finding the defect is only the first step. Inspection is just part of the process. Repair is the other part, and they need resources to correct the problem. It is easier to find the places that need repair than it is having the resources to do the repair.
- A respondent stated that the track safety rules do not allow a lone worker to go into a control point, which hinders the inspection process. He believes that is safe; they were able to do it safely before RWP and should be allowed to do it now.
- One supervisor believes that older smaller rail (90 lbs) should be upgraded to the standard 6-inch base and 119+ lb weights. The smaller rail is old and brittle.

- One respondent commented on the significant move towards a more automated inspection process; it should not replace on-foot inspection, especially in areas with passenger trains. In his view, any attempt to replace visual or on-foot inspection with automated inspection is not acceptable. Automated inspection is a supplemental tool and should not reduce or replace visual or on-foot inspection.

Appendix F.
Results of Interviews with Division Engineers

Number of Interviewees	5

How long have you been a division engineer?

Range	10 months to 12.5 years
Median	3.5 years

How many years of experience do you have doing track inspection or supervision?

Range	20 to 35 years
Median	24.0 years

How large is your division (track miles)?

Range	746 to 2356 track miles
Median	1500.0 track miles

How many territories (subdivisions) are in your division?

Range	5 to 14 subdivisions
Median	7.0 subdivisions

How many track supervisors/roadmasters report to you?

Range	5 to 14 track supervisors / roadmasters

(Note: Four out of the five division engineers reported that they supervise either five or six track supervisors; the remaining division engineer reported that he supervises 14 track supervisors.)

What characteristics of your division create challenges for the track inspection process?
The following were mentioned:

- Heat, rivers, soil compaction
- Weather, high winds, floods
- Roadway Worker Protection (RWP) rules, curves, tunnels, volume/density of traffic, foul time (dispatcher workload)
- Roadbed, yards and abutting industries

What territory characteristics trigger special inspections?

Extreme heat	5/5
Extreme cold	4/5
Desert terrain	0/6
Mountain terrain	1/6
Other*	3/6

*Other items mentioned:
- Severe weather
- Storms, bridge strikes, rough ride reports, ARMS hits, train partings, tunnels, corroded rail
- Flooding

What criteria do you use to establish inspection territories?
- Number of trains versus miles, and number of switches and curves.
- Mileage and type of track (CWR vs. jointed rail) and class of track
- # of mainline tracks, yards, sidings, class of track
- Roadbed, yards and abutting industries
- Track miles/tonnage

What is the average size of an inspector's territory in your division?
Miles of mainline track:

Range	10 to 110 miles
Median	83.0 miles

Number of yard sites:

Range	3 to 26 sites

How do you determine how many inspectors you need on a territory?
- Curves, turnouts, miles of track
- Mileage
- # of mainline tracks, yards, sidings, class of track
- Total number of main and industry tracks along with number of yard tracks
- Determined by chief engineer

Do you feel that you have an adequate number of inspectors on your division?

Yes	5/5
No	0/5

How did you make that determination?
- Watching inspections ensuring they have adequate time to inspect assets.
- Experience
- Average total miles and yard tracks

Note: The methodology for determining the number of inspectors and whether or not the current number is adequate is not an exact science. These decisions seem to be based on experience.

Do you conduct a morning call with your track supervisors/roadmasters?
Only one division engineer (DE) reported conducting a daily morning call. Topics for his calls include RWP, previous night's work, work to be scheduled for inspectors and revisions to standards or engineering practice. The other four DEs reported having a weekly call with roadmasters. Topics for weekly conference calls include: discussion of incidents at the local, regional and system level; proactive activities related to personal safety, derailment prevention

and public safety issues; and identification of trends related to inspection compliance requirements. One DE reported a nightly report from roadmasters on activities including daily and weekly plans, service interruptions, etc.

What types of training does your railroad provide for track inspection personnel?

On-the-job:

More frequently than annually	5/5

FRA track standards training:

Less than biennially	3/5
Biennially	1/5
Annually	1/5

FRA safety standards training:

Biennially	2/5
Annually	2/5
More frequently than annually	1/5

Other track inspection related training:

- Heat and cold inspections, track stability (twice annually)
- Field visits by staff to discuss revisions, standards, new practices or policies, derailment findings
- Annual additional geometry-related training

How frequently do your inspectors work overtime?

One person responded "often." Other responses were "hardly ever" to "occasionally." Reasons for overtime were: weather, mostly track and time or dispatcher related issues, assignment to non-inspection duties, short-staffed, and covering vacations, holidays and absenteeism.

What types of automated inspections occur on your division? How frequently? In what way are they useful?

Type of inspection (# using)	**Frequency (# responding)**
Ultrasonic rail flaw detection (5/5)	• 30 to 90 days depending on territory (1/5) • Core route 12 times per year; more in winter than summer (1/5) • Two times per year (1/5) • Every 45 days; also test high-volume yard track (1/5) • Eight times per year (1/5)
GRMS (4/5)	• Annually (3/5) • Subdivision specific; used in areas of marginal tie condition (1/5)
TGMS (5/5)	• Four times per year (2/5) • Twice per month (1/5) • Biannually; good experience for new inspectors (1/5) • Three times per year (1/5)
VTI (4/5)	• Monthly (2/5) • Impact detectors (wayside) only (1/5) • ARMS (Automated Remote Monitoring System) – 16 units daily

Other types of inspection:
- Rail wear (same vehicle as gage restraint)
- FRA track geometry car – 2 times/year

Does your railroad inspect more frequently than FRA regulations require?

Yes	5/5
No	0/5

Examples are:
- On heavy tonnage lines we inspect every day
- On gas welded rail and in adverse weather
- On routes with passenger service
- Special inspections (extreme heat, cold, etc.)
- Monitor wear for compliance with rail change out standards

The only reason offered for more frequent inspection was, “For safety reasons; look for broken rail and joint issues.”

Does your railroad inspect to FRA minimum safety standards or are your standards more stringent?

Three reported having more stringent standards. Examples were:
- Gage and surface defect tolerances tighter by 1/8"
- Rail changeout standards

Reasons for the more stringent standards:

- Safety
- Make repairs before they become defects

Are there any other inspections that you would find helpful?

- Working on ground penetrating radar for fouled ballast and tie support; need joint bar testing for jointed rail
- VERSE (rail uplift) testing (for CWR)

What changes, if any, would you recommend in current FRA track inspection requirements?

- Need better definitions, e.g. monthly versus 30 days needs changing. More use of hand-held recording devices; electronic instead of paper.
- Rewrite tie defect definition to make it clearer.

Are there any other aspects of the inspection process that you would like to comment on for FRA consideration in preparing its Report to Congress?

There were no further comments.

Appendix G.
Results of Interviews with System Level Officers

Number of interviewees	6

How long have you been in your current position at your railroad?

Range	1 to 8 years
Mean	4.2 years
Median	4.0 years
Standard deviation	2.3 years

How many years of experience do you have doing track inspection or supervision?

Range	15 to 35 years
Mean	27.0 years
Median	28.0 years
Standard deviation	6.8 years

How many miles of track does your railroad have?

Range	1943 to 39,700 miles
Mean	23,866.3 miles
Median	26,500.0 miles
Standard deviation	15,031.8 miles

How many track inspection personnel, both inspectors and supervisors, do you currently employ?

Range	74 to 881 inspection personnel
Mean	358.8
Median	294.0
Standard deviation	301.4

How do you determine if your number of inspection personnel is adequate?
The number is based upon the railroad's previous experience and the ability of the inspectors to complete their territory in the allocated time.

What is the typical size of a track inspector's territory on your railroad?
The responses to this question were not included in this summary because the system level officers oversee large areas that encompass many divisions and large numbers of inspectors, and the system level officer's response to this question would not provide a specific response to this question.

What types of training does your railroad provide for track inspection personnel?
On-the-job:

More frequently than annually	6/6

FRA track standards:

More frequently than annually	1/6
Annually	3/6
Biennially	2/6

FRA safety standards:

More frequently than annually	2/6
Annually	4/6

Other training:

CWR training – annually	1/6
Track buckle and washout classes – annually	1/6
Inclement weather training – annually	1/6
REDI Center	1/6

How do you determine whether inspection should be on foot or via hi-rail?

- Traffic density
- Compliance with FRA standards
- Track accessibility

Does your railroad have a recommended speed for hi-rail inspections?

Yes	2/6
No	4/6

Do you have a maximum speed for inspections?

Yes	3/6
No	2/6
Unsure	1/6

How did you establish these speeds?

- Experience
- To fit conditions and inspection requirements
- FRA recommendations
- Type of track and track characteristics

Does your railroad inspect more frequently than FRA regulations require?

Yes	6/6
No	0/6

Examples are:

- Inspect at twice the FRA required frequency on key routes.
- Three visual inspections per week if over 10 MGT/year.

Does your railroad inspect to FRA minimum safety standards or are your standards more stringent?

Standards are more stringent	3/6
Some standards are more stringent	2/6
No response	1/6

Examples are:

- Replace flawed rail earlier than required by FRA standards.
- Perform a walking inspection of each critical yard track at least two times per month with at least 10 days between inspections.

What types of automated inspections occur on your railroad? How frequently? In what way are they useful?

Type of inspection (# using)	Responses
Ultrasonic rail flaw detection (6/6)	The reported frequencies vary depending on the type of track, its tonnage and railroad. Generally varies between twice a month to once a year. Recent improvements in ultrasonic testing technology to help find defects masked by shells or spalls have proven very beneficial.
GRMS (4/6)	At least once a year.
TGMS (6/6)	Respondents indicated that they use TGMS between once a year to twice weekly. The most common response was four times a year.
VTI (5/6)	Dependent on locomotive schedules.

Other types of inspection:

- Optical joint bar inspection vehicle, some specified Herzog or digital imaging
- Aurora laser system to locate and prioritize areas of concrete tie rail seat abrasion.

Are there any other inspections that you would find helpful?

- More accurate methods to locate cracks in joint bars.
- Rail seat abrasion measurements need improvement – currently the Aurora system has 70-percent accuracy.

What changes, if any, would you recommend in current FRA track inspection requirements?

- 213.53 Gage: Would like to see allowable tight gage differ up to three-quarters of an inch from standard gage.
- 213.137 Frogs: Would like to see part (d) eliminated or modified to allow for use of flange-bearing frogs in all classes of track without a waiver.
- 213.143 Frog guard rails and guard faces; gage: Would like to see this eliminated and replaced with “width of opening from guard face of guard rail to gage face of running rail must not exceed 1⅞ inches.”
- Northeast Corridor should go to weekly inspection versus twice weekly because of the additional inspections done by geometry cars.

- CWR regulations need modification to allow railroads to use their own experience. Additionally, eliminate requesting FRA approval to change CWR policy if more stringent than FRA standards. Note: This comment was mentioned by two respondents.
- Include yard rail testing which FRA doesn't currently cover.
- Fewer requirements.
- Different standards for metro areas.

Are there any other aspects of the inspection process that you would like to comment on for FRA consideration in preparing its report to Congress?

- Do not change anything that keeps railroads from capitalizing track.

Appendix H.
Ideal Observer for Visual Track Inspection

H.1 Theory of the Ideal Observer

One way to determine the maximum speed at which a visual track inspection can occur is to construct a theory of the ideal observer. The ideal observer provides an upper limit on how well the best possible observer can perform by making optimal use of the information available from the stimulus (Wickens 2002). In the present case, the maximum speed will depend critically upon human visual and cognitive capabilities and limitations. To the extent that all relevant human capabilities and limitations are known and are accurately captured, the ideal observer provides a benchmark against which actual performance and practices can be compared. In the present case, the ideal observer can serve as a comparison to practices reported in surveys, interviews and focus groups regarding the speed at which visual inspections are routinely performed. Maximum speed in miles per hour (mph) can be defined as

$$mph = r / t \tag{1}$$

where r is the distance from the observer to the object to be detected and t is the exposure time, which is the amount of time required by the observer to detect the object with some degree of accuracy.

H.2 Human Factors Considerations

There are several aspects to this from a Human Factors point of view that must be considered:

1. Visual acuity and detection accuracy
2. Visual search time
3. Attention (vigilance, distraction, fatigue)

H.2.1 Visual Acuity

Visual acuity is the limit in the ability to resolve detail (Boyce 1997, p. 872). Visual acuity is generally specified in terms of the visual angle (θ) between the observer's eye and the largest dimension (l) of the object being viewed.

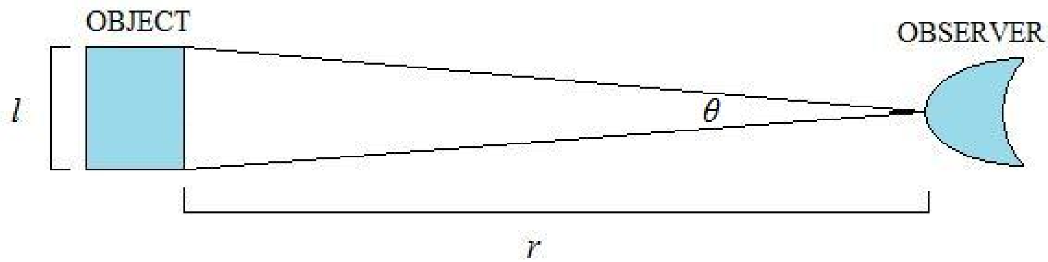

Figure 21. Diagram of observer, object, and relevant parameters

If θ is small, then

$$\theta = \frac{57.3l}{r} \qquad (2)$$

in degrees (Graham 1951, p. 872), where r is again the distance of the object from the observer.

Visual acuity (θ) is a function of *light intensity* and *exposure time* (Riggs 1972, p. 300).

Light Intensity. If we assume that track inspections take place during daytime and under good visibility conditions, visual acuity is at a plateau of approximately 0.5 minutes of arc (Bartley 1951, p. 958). This, however, is a threshold value (50-percent detection). Visual acuity in the psychophysics literature is generally expressed as the smallest visual angle at which detection can occur with 50-percent accuracy. Detection accuracy is best thought of as a probability: accuracy can approach zero and 100 percent, but never reaches either limit. A detection accuracy of 50-percent (probability = 0.5) is considered the detection threshold in classical psychophysics. Intuitively, a much higher detection accuracy for safety critical tasks, such as track inspection, would be desired. A rule of thumb suggested by Boyce (1997, p. 873) is that the visual angle needs to be four times bigger than the threshold for quick resolution without affecting visual performance. However, a fourfold increase in the visual angle from the threshold only results in 59.5-percent correct detection (see Appendix H.3 to this report, or Egan 1975, p. 81 for computational details and definitions of signal-to-noise ratio S/N and $d'_{Y/N}$). A value above 90 percent would seem better-suited for a safety-critical task. Table 1 shows the visual angles for 50-, 59.5-, 90-, 95-, and 99-percent correct detection.

Table 1. Visual Angle, S/N, d' and Percent Correct Detection.

Percent Correct Detection	***d'*$_{Y/N}$**	***S/N***	**Visual Angle, θ (min arc)**
50	0.085	1.0	0.5
59.5	0.34	4.0	2.0
90	1.82	21.4	10.71
95	2.33	27.45	13.73
99	3.29	38.77	19.38

Exposure Time. The Bunsen-Roscoe Law of photochemistry is obeyed if the eye is exposed to light for short periods of time, such that the amount of energy (E) needed to detect an object is constant and E is the product of time (t) and luminance (L). This law does not apply above a critical duration, t_c. Above t_c luminance alone determines acuity. Values of t_c range from 0.01 to over 0.2 seconds. So, to set exposure time, according to Riggs (1972, p. 304):

> The duration of the best 'look' must be greater than t_c, but it need not be longer than one or two tenths of second at daylight levels of luminance.

Accordingly, we set minimum exposure time (t) at 0.2 seconds.

It is now possible to specify the maximum speed at which objects of various sizes can be detected with a particular degree of accuracy by combining equations (1) and (2):

$$mph = \frac{57.3l}{t\theta} \qquad (3)$$

This is shown in Figure 22 for 50-, 59.9-, 90-, 95-, and 99-percent correct detection rates.

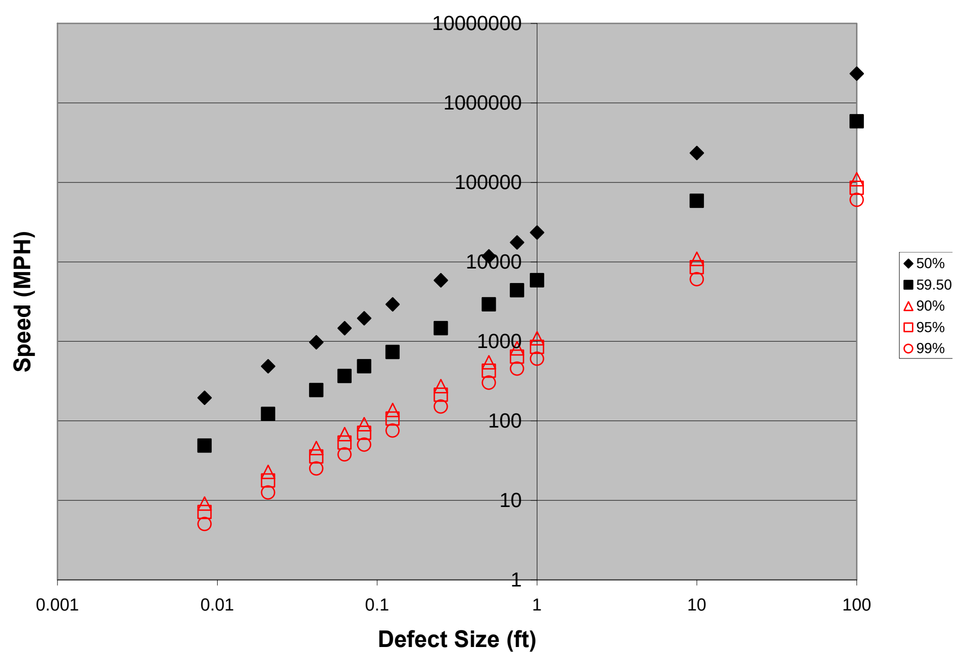

Figure 22. Relationship between maximum inspection speed, defect size and detection accuracy

The size of the smallest object that must be detected would set the limit on track inspection speed considering only visual acuity and desired detection accuracy. The smallest object in Figure 1 is 0.1 inches and can be detected with a 99-percent detection rate at 5 mph. The same object would be detected 90 percent of the time at approximately 9 mph. At threshold, the object would be detected 50 percent of the time at a speed of 195 mph–not a practical speed or track inspection approach, of course.

H.2.2 Visual Search

Visual search time has been extensively studied and an excellent summary of that work can be found in Luce (1986, p. 428). The average time required to search for an item is given by

$$S = kM + r_0 \qquad (4)$$

where k is the mean time per item, M is the number of items, and r_0 is the residual time. The values of k and r_0 are 40 milliseconds (msec) and 400 msec, respectively. The search time would include the exposure time in order to estimate total time available to traverse the distance to the object. In a case where there is only one object to be found in an otherwise blank field (an unrealistic scenario, but one which sets a lower boundary), the search and exposure time would be 440 msec. If we substitute S in equation (4) for t in equation (3), the maximum speed for track inspections is now

$$mph = \frac{57.3l}{S\theta} \qquad (5)$$

Figure 23 shows this relationship for 90-percent accuracy, Figure 24 shows the relationship for 95-percent accuracy, and Figure 25 shows the relationship for 99-percent accuracy.

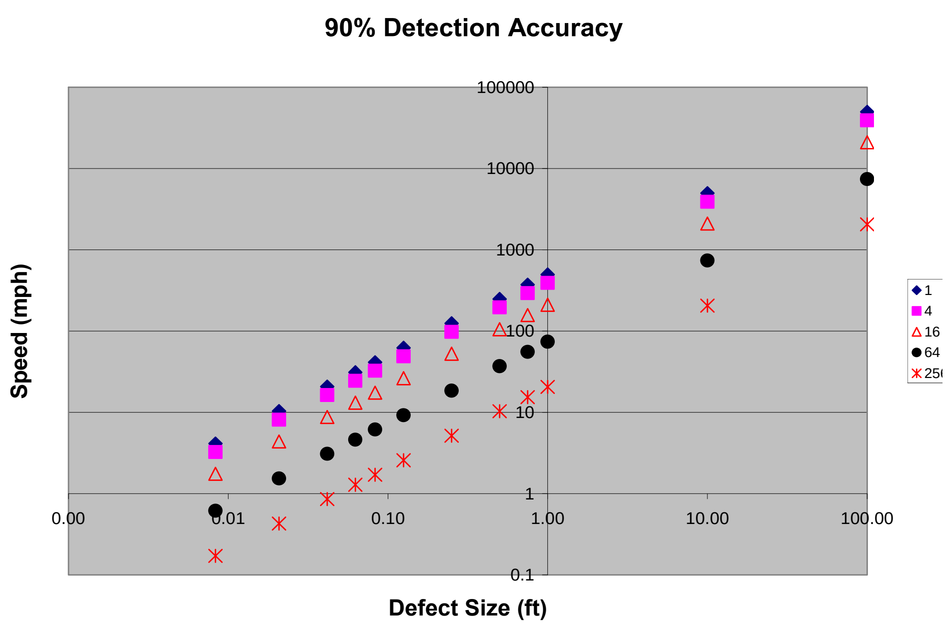

Figure 23. Relationship between maximum inspection speed, defect size, and number of search objects for 90-percent detection accuracy

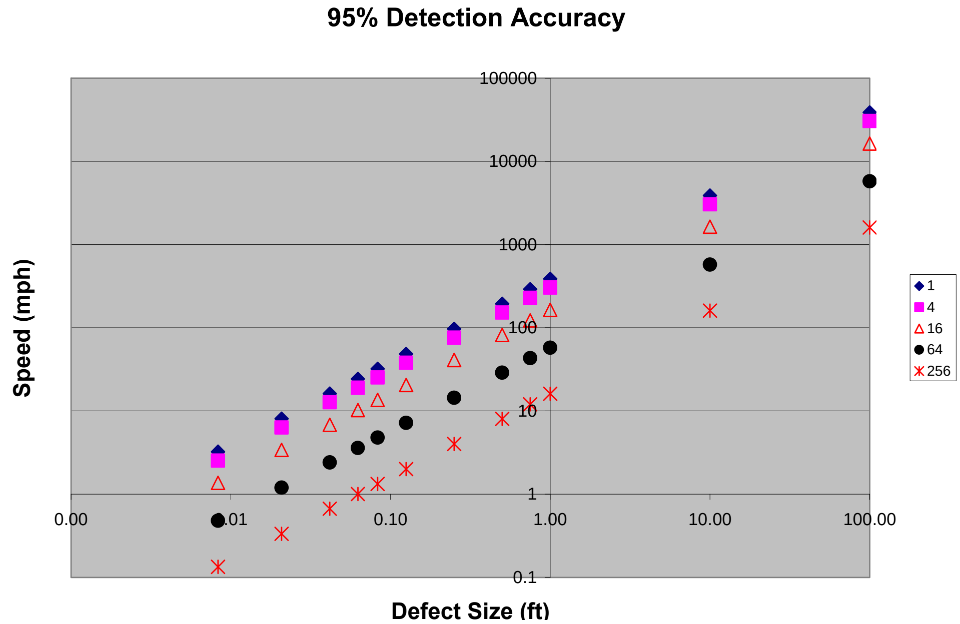

Figure 24. Relationship between maximum inspection speed, defect size, and number of search objects for 95-percent detection accuracy

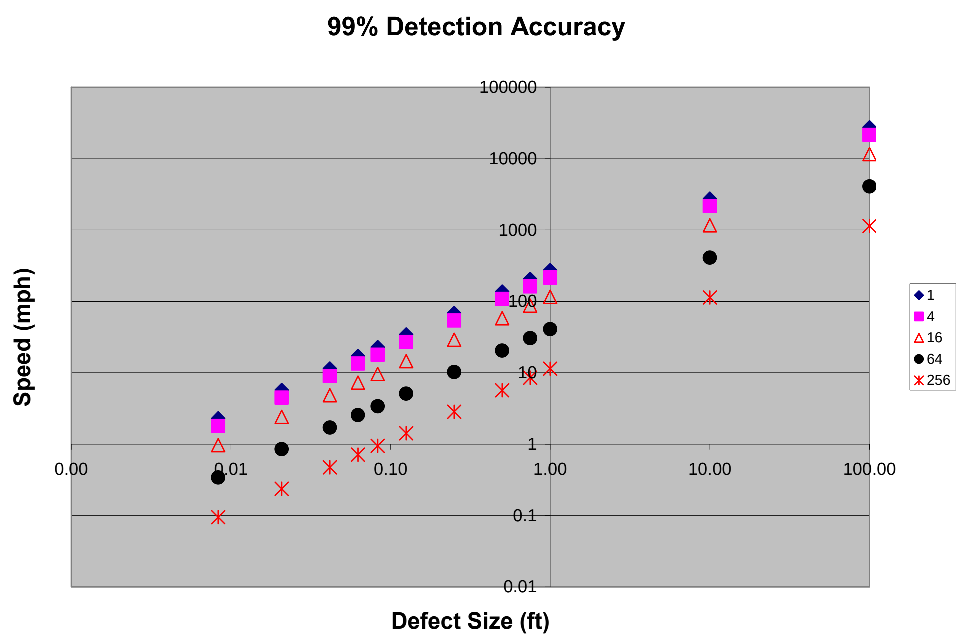

Figure 25. Relationship between maximum inspection speed, defect size, and number of search objects for 99-percent detection accuracy

It is easy to see that as the number of search objects increases, the time to search increases; so, the speed of the inspection must decrease. Again, using the smallest object (0.1 inch) as the example, maximum speed with 90-percent accuracy is approximately 4, 3, 1.75, 0.6, and 0.2 mph; with 1, 4, 16, 64, and 256 objects to search. At 95-percent accuracy, maximum speed is approximately 3, 2.5, 1.4, 0.5, and 0.13 mph; with 1, 4, 16, 64, and 256 objects to search. At 99-percent accuracy, maximum speed is approximately 2.3, 1.8, 1, 0.3, and 0.1 mph; with 1, 4, 16, 64, and 256 objects to search.

H.2.3 Attention

Attention, including vigilance, distraction, and fatigue, is a complex issue to model in a task like track inspection. It should be noted that this is a broad subject with many components that may require separate consideration. For example, if one is fatigued, it may be easier to be distracted and harder to maintain vigilance. However, for purposes of this discussion, we will simplify and consider a track inspection task to be primarily a vigilance task. This is consistent with the need to search for defects among multiple distracters (search objects) while visual information is flowing by at the speed of inspection.

The original studies on vigilance were performed by Mackworth (1950), and subsequent studies have found the basic phenomenon to be robust. According to Boff and Lincoln (1988, Vol II, p. 1504):

> The correct detection of signals (hit rate) in most simple vigilance tasks shows a decrement over time. When hit rate is averaged for blocks of time (e.g., 30 min) in a 2-hr task, the vigilance decrement is greatest between the first and second blocks.

According to Luce (1986, p. 176), at low signal rates correct detections in the Mackworth vigilance experiments fell from 85 percent in the first half hour to 73 percent in the rest of the watch. This corresponds to a change in $d'_{Y/N}$ from 1.47 to 0.86 or 0.61 units.

Thus, to maintain performance at a desired level of percent correct detection it would be necessary to increase the visual angle sufficiently to compensate for this amount of vigilance decline after the first half hour.

Figure 26, Figure 27, and Figure 28 show the relationship between maximum inspection speed, defect size and number of search objects for vigilance decrement adjusted detection accuracy.

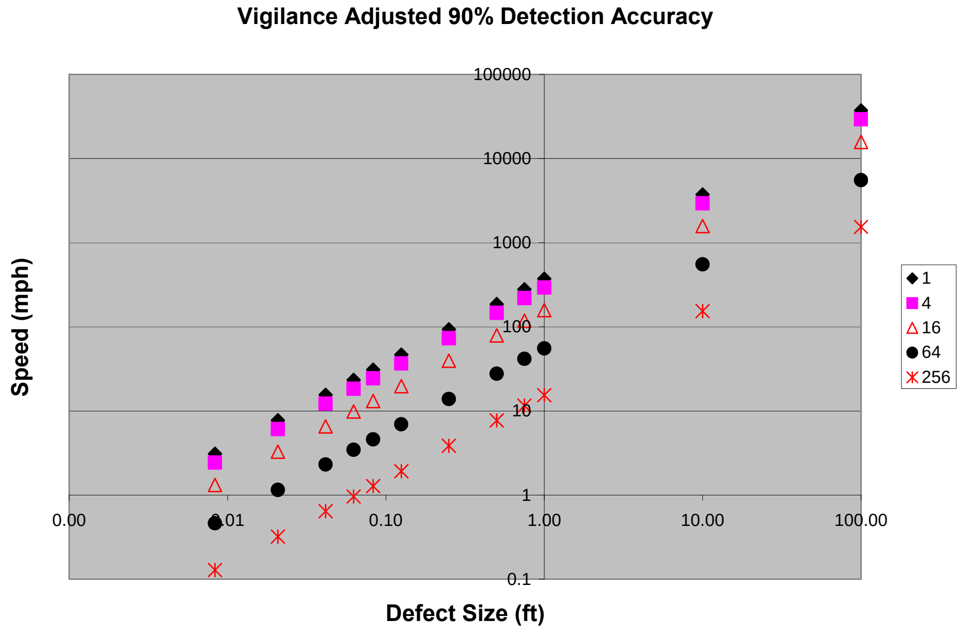

Figure 26. Relationship between visual inspection speed, defect size, and number of search objects for vigilance-adjusted, 90-percent correct detection accuracy

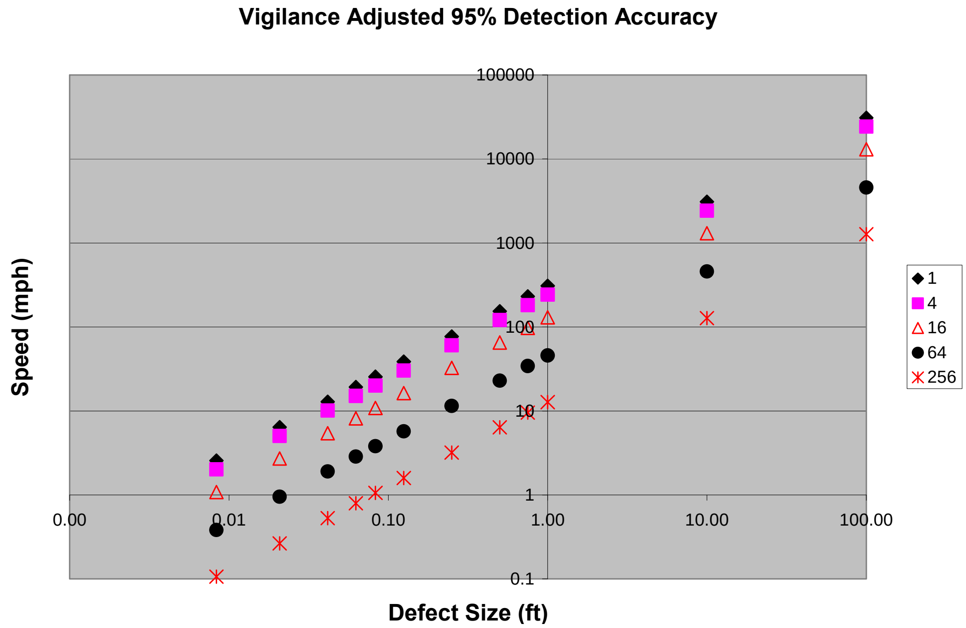

Figure 27. Relationship between visual inspection speed, defect size, and number of search objects for vigilance-adjusted, 95-percent correct detection accuracy

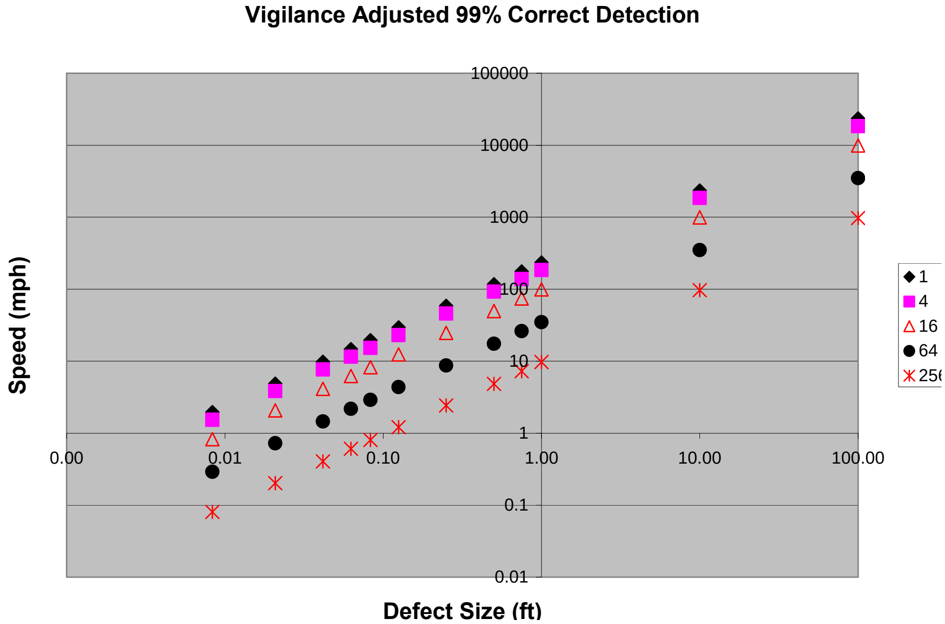

Figure 28. Relationship between visual inspection speed, defect size, and number of search objects for vigilance-adjusted, 99-percent correct detection accuracy

H.3 ADDENDUM: Visual Angle (θ) and Probability of Correct Detection

Green and Swets (1966, p. 190) provides the basis for the Boyce (1997) rule of thumb, and conveniently, Green and Swets' Signal Detection Theory (SDT) provides a means of relating the probability of a correct decision to the *S/N*, and ability to detect (sensitivity or *d'*). For this discussion we assume that signal-plus-noise and noise distributions are normally distributed.

In a normal distribution probabilities are often expressed as z-transformed scores, where

$$\Phi(z) = \Phi\left(\frac{x-\mu}{\sigma}\right) = \int_{-\infty}^{z} \frac{1}{(2\pi)^{1/2}} \exp\left(\frac{-t^2}{2}\right) dt \qquad \text{(A1)}$$

We know that the threshold value of θ is 0.5 min of arc, which means that the probability of a correct decision is 0.5. This corresponds to a z-score of 0. Because equation (A1) is difficult to evaluate, extensive tables exist to relate probabilities and z-scores.

To relate θ to the probability of a correct decision, it is necessary to discuss two different observation paradigms and how they relate to *S/N*. By definition, at threshold, $S/N = 1$. Empirically, however, the relationship between *d'* and *S/N* depends on the particulars of the observation paradigm and local conditions.

In a simple Yes/No paradigm (Y/N), observers are presented with a single observation interval and are asked to respond "yes" if a stimulus is present or "no" if a stimulus is not present (no-stimulus). It is known that observers will be biased to say "yes" if the probability of a stimulus interval is greater than a no-stimulus interval, and vice-versa. However, even if the probability of stimulus and no-stimulus intervals are the same, the observer's perceived probability of stimulus and no-stimulus intervals may not be equal, and bias may still result. The consequence of this is that $d'_{Y/N}$, the measure of sensitivity in Y/N, can have considerable response bias associated with it. In general, sensitivity is defined as

$$d' = z(Hit) - z(FA) \qquad \text{(A2)}$$

If there is no bias in the observation paradigm,

$$z(Hit) = z(FA) \qquad \text{(A3)}$$

In Y/N, $d'_{Y/N} = z(Hit) - z(FA)$, and it is assumed that $z(Hit) \neq z(FA)$.

In a 2 Interval Forced Choice (2IFC) observation paradigm, observers are presented with two observation intervals, one of which contains the stimulus. The order of the stimulus and no-stimulus intervals is random, and the observer must identify the interval that contained the stimulus. This is clearly an artificial situation, but it is very useful because it does not produce response bias. In 2IFC, the measure of sensitivity is d'_{2IFC}. The 2IFC paradigm is unbiased, so that

$$d'_{2IFC} = z(Hit) - z(FA) \qquad \text{(A4)}$$

and $z(Hit) = z(FA)$. Because there are two observation intervals in 2IFC, the relationship between sensitivity in Y/N and 2IFC is

$$d'_{2IFC} = 2^{0.5} d'_{Y/N} \qquad \text{(A5)}$$

This allows the artificial observation paradigm of 2IFC to be directly compared with or translated into the more natural observation paradigm of Y/N. Moreover, in 2IFC, the probability of a correct decision (A) is

$$A = p(Hit) = p(FA) \qquad \text{(A6)}$$

Consequently, if one wishes to set the sensitivity of the Y/N paradigm in terms of the probability of a correct decision, one could easily use a table of the normal distribution to determine the value of *z(Hit)* associated with A and double *z(Hit)* to obtain d'_{2IFC}. Equation (A5) would then be used to determine $d'_{Y/N}$.

Empirically, Green and Swets (1966, p. 190) found that

$$d'_{Y/N} = 0.085\frac{S}{N} \qquad \text{(A7)}$$

At threshold, by definition $S/N = 1$, so $d'_{Y/N} = 0.085$.

In the case of visual acuity, this means that when $\theta = 0.5$ min, $d'_{Y/N} \approx 0.085$, $A \approx 0.5$ or 50 percent.

For the Boyce (1997) rule of thumb, a fourfold increase from threshold gives $\theta = 2$ min.
From (A7), $d'_{Y/N} = 0.085 \times (2/0.5) = 0.34$
From (A5), $d'_{2IFC} = 0.34 \times 1.414 = 0.48$
From (A4), $z(Hit) = 0.5 \times d'_{2IFC} = 0.24$
From tables of the normal distribution, $A = 0.599$ or 59.9 percent

As an example, if we want the value of θ that has a 90 percent correct detection:

From tables of the normal distribution, if $A = 0.9$ or 90 percent, then $z(Hit) = 1.29$,
From (A4), $d'_{2IFC} = 2 \times z(Hit) = 2.58$
From (A5), $d'_{Y/N} = d'_{2IFC}/1.414 = 1.82$
From (A7), $S/N = d'_{Y/N}/0.085 = 21.4$
Therefore, $\theta = 21.4 \times 0.5 = 10.7$ min

As a further example, if we want the value of θ that has a 99 percent correct detection:

From tables of the normal distribution, if $A = 0.99$ or 99 percent, then $z(Hit) = 2.33$,
From (A4), $d'_{2IFC} = 2 \times z(Hit) = 4.66$
From (A5), $d'_{Y/N} = d'_{2IFC}/1.414 = 3.29$
From (A7), $S/N = d'_{Y/N}/0.085 = 38.77$
Therefore, $\theta = 21.4 \times 0.5 = 19.38$ min

Appendix I. RSAC Recommended Definition of "Qualified Operator" in 49 CFR § 213.238

§ 213. 238 Qualified operator

Each provider of rail flaw detection shall have a documented training program in place and shall identify the types of rail flaw detection equipment on which each operator has received training and is qualified.

(a) A qualified operator shall be trained and shall have written authorization by the employer to:

(1) Conduct a valid search for internal rail defects utilizing specific type(s) of equipment they are authorized and qualified to operate;
(2) Determine that such equipment is performing as intended;
(3) Interpret equipment responses and institute appropriate action in accordance with the employer's procedures and instructions;
(4) Determine that each valid search for an internal rail defect is continuous throughout the area inspected and has not been compromised due to environmental contamination, rail conditions, or equipment malfunction.

(b) The operator must have received training in accordance with the internal documented training process and complete a minimum of 160 hours rail flaw detection experience under direct supervision of a qualified operator or rail flaw detection equipment manufacturer representative. The operator must demonstrate proficiency in the rail defect detection process, including equipment to be used, prior to initial qualification and authorization by the employer on each type of equipment.

(c) Re-evaluation and any necessary recurrent training shall be determined in accordance to a documented internal policy. The re-evaluation and recurrent training can consist of a periodic review of test data submitted by the operator as determined by an internal audit process. The re-evaluation process shall require that the employee successfully complete a recorded examination and demonstrate proficiency to the employer on the specific equipment type(s) to be operated.

(d) Each employer of an authorized qualified individual shall maintain written or electronic records of each qualification in effect. Each record shall include the name of the employee, the equipment to which the qualification applies, and the date of qualification and date of most recent successful re-evaluation.

(e) Employees that have demonstrated proficiency in the operation of rail flaw detection equipment prior to the date of promulgation shall be grandfathered into the program and considered a qualified operator, regardless of the previous training program they were qualified under.[1] Such grandfathered operators shall be subject to paragraph (c).

(f) Qualification records, as well as a copy of equipment-specific training programs and materials, recorded examinations, demonstrated proficiency records, and authorization records, shall be kept at a location designated by the employer; and available for inspection and copying by the Federal Railroad Administration during regular business hours.

[1] This rule has not yet been published.

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