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## REVIEW OF RAIL-TESTING PRACTICES AND TECHNOLOGIES — NORTH AMERICA

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### Summary

A review of rail-testing technology and practices on North American freight railroads focused on technology, equipment utilization, and the regulatory environment — three major factors that influence the effectiveness of rail testing.

The study showed that:

- Contractors currently provide the primary impetus for research and development in the area of testing technology.
- Major innovations are in the development of improved analysis techniques to assist the operator in analysis of the test data.
- A major area of focus with regard to rail-testing technologies is the accuracy and reliability of the tests.
- Risk management is emerging as a key factor in the development of rail-testing strategies, with a strong focus on maintaining a constant and acceptable level of risk.
- Current scheduling equations used by railroads make use of defined levels of risk (which vary with traffic type), together with such key factors as defect history and traffic (tonnage) levels to set testing frequencies.

Current North American railroad practice is to operate a test vehicle only until the defects found can be handled by the rail-replacement crew following the car. This practice, which is driven in part by the North American regulatory and legal environment, limits daily productivity and is being addressed by use of waivers to provide a time delay between detection and repair action, improving technology to increase reliability (reduce false alarms) and increase test speed, and improving replacement practices (e.g. higher-performance gangs) to accelerate the rate of defect replacement.

This survey is a part of the joint effort by the Association of American Railroads (AAR) and Federal Railroad Administration to improve the reliability of rail-flaw detection, and was conducted under the AAR-funded Track Integrity Strategic Research Initiative. A companion Technology Digest (TD — 98-016) describes findings from an overseas survey on the same subject matter.

*\*Policies and procedures outlined herein were determined by the contractor, Zeta-Tech Associates, Inc., and do not necessarily represent opinions of the Association of American Railroads or Transportation Technology Center, Inc.*



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## INTRODUCTION AND CONCLUSIONS

As part of its Strategic Research Initiative on Improved Rail Integrity, the Transportation Technology Center, Inc. (TTCI), contracted with Zeta-Tech Associates, Inc., to prepare an overview of current and emerging rail-flaw testing technologies and practices used by railroads and railroad-testing contractors in North America.

When dealing with rail flaws, risk management was found to be of particular significance, including the use of rail-defect inspection data to optimize test schedules. It also addresses the selection of an effective inspection strategy to maximize the effectiveness of the testing while minimizing total system costs.

The study showed that:

- Test contractors currently provide the primary impetus for research and development in the area of rail-testing technology.
- Innovative strides are under way to improve analysis techniques to assist operators in interpreting test data.
- Major areas of focus with regard to rail-testing technologies include improving accuracy and reliability of tests. These two factors are distinct, with accuracy referring to the size of the defect that can be detected and reliability referring to the percentage of time that size defect is found. Contractor data indicates that the reliability of current inspection technology is in line with American Railway Engineering and Maintenance of Way Association (AREMA) guidelines, chapter 2.2.4. Inspection reliability increases with defect size, with a high probability (greater than 90 percent) associated with medium to large defects (usually defined as defects larger than 20 percent of head area).
- Risk management is emerging as a key factor in the development of rail-testing schedules and strategies with a strong focus on maintaining a constant (and defined) level of risk.
- Current rail-test scheduling equations used by railroads make use of defined levels of risk which vary with traffic type, combined with such key factors as defect history and traffic (tonnage) levels to determine testing frequencies.

- Current North American railroad practice is to operate a test vehicle only until as many defects are found as can be handled by the rail-replacement crew following the car that same day. This practice is driven in part by the North American regulatory and legal environment.

## INSPECTION TECHNOLOGY

Ultrasonic inspection technology remains the primary technology in use in North America today. The majority of the testing units in use are hi-rail vehicles. Also operating are a few larger rail-bound units, some of which include both ultrasonic and magnetic-induction technologies.

Major innovative strides are under way in the development of improved ultrasonic signal-analysis techniques to assist operators in data interpretation. These techniques, which make use of fully digital signal-processing software combined with pattern-recognition logic, allow for the recognition of defect and/or track features to help in quickly and accurately locating defects and separating defects from non-defect events.

Another technological focus is on finding "hidden" defects. This includes use of improved transducer configurations, improved processing software, and utilizing multiple testing technologies (e.g. ultrasonic and magnetic induction).

Exhibit 1 presents contractor-defined levels of accuracy for both ultrasonic-only, and combined ultrasonic and magnetic-induction detector cars.

DEFECT TYPE	DEFECT SIZE
Transverse Defect (TD)	5%
Detail Fracture (DF) (ultrasonic only)	10%
Detail Fracture (DF) (combined ultrasonic/magnetic induction)	5%
Vertical Split Head (VSH)	6"+
Joint Defects	1/2"+
Engine Burns with Transverse Component	15%
Horizontal Split Head (HSH)	2"+
Head and Web Separations	1/2"+
Defective Welds; Centrally Located	5%
Defective Welds; Not Centrally Located	10%
Defective Welds; Horizontal Plane Defects	2"+

**Exhibit 1. Testing Accuracy Showing Size of Defect that can be Found with High Level of Confidence**

(Note: These accuracies are based on engineering judgment of defects found after multiple passes.)

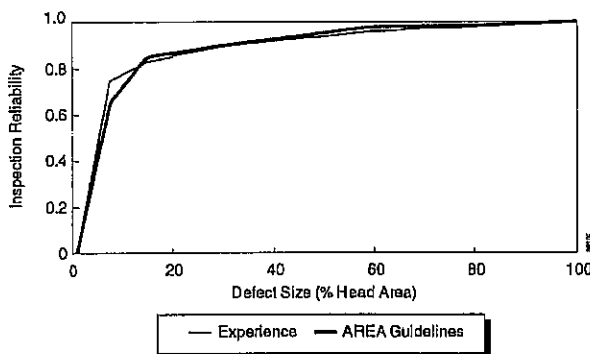
Reliability is a key issue in determining the associated level of "risk" that a defect will not be found and will thus break in service. The most commonly defined value for this level of risk is the ratio of service failures (defects not detected by testing but found in the field) to total defects (service plus detected defects). These values generally show that between 74 percent and 90 percent of all defects are found by testing, corresponding to service/total defect ratios of between 0.1 and 0.26. However, since this ratio does not relate reliability to rail size, it is not, by itself, a fully adequate means of defining inspection reliability. A more representative means of defining inspection reliability relates reliability to defect size, using the relationship:

$$\text{Inspection Reliability (IR)} = [0.217 \times \ln (\% \text{ defect size})]^n$$

where % defect size refers to the size of the defect (in % head area) and  $n$  is a constant. The "experience" curve in Exhibit 2 corresponds to a value of  $n = 0.35$ , and represents the estimated reliability experienced by one testing contractor for detail fracture defects.

AREMA has also defined reliability for rail testing. Exhibit 2 compares the AREMA guidelines for transverse defects (based on mid-range value), with the contractor "experience" data and shows good correlation between the AREMA guidelines and reported experience. In all cases, inspection reliability increases with defect size, with a high reliability (greater than 90 percent) associated with medium to large defects (larger than 20 percent head area).

Test contractors currently provide the primary impetus for research and development in the area of



**Exhibit 2. Inspection Reliability as a Function of Defect size; Comparison of Experience with Guidelines**

rail-testing technology. Development areas include:

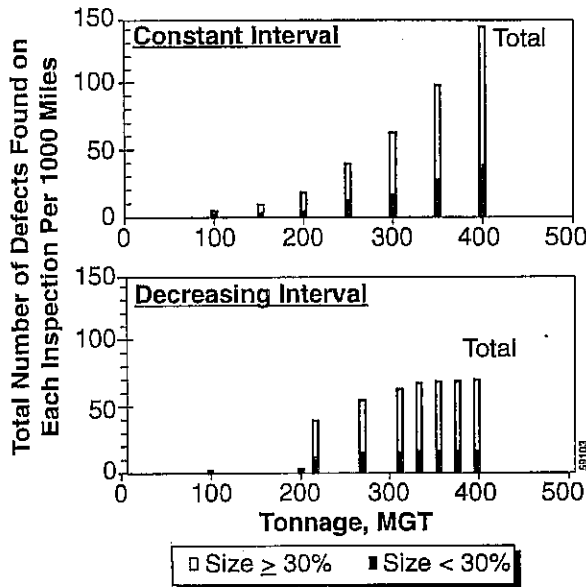
- Improved signal analysis and pattern recognition
- Separation of high-speed (continuous) testing from low-speed (hand) verification
- Improved detection capability for difficult defects
- Downsizing of magnetic-induction systems to fit on hi-rail vehicles
- Improved carriage control and railhead tracking
- Higher testing speeds
- Monitoring of ongoing research in areas such as electromagnetic acoustic transducers and neural networks

#### NORTH AMERICAN RAILROAD PRACTICES

Improved scheduling of test equipment depends both on the level of testing technology and the level of risk that can be tolerated by the railroad. Historically, this level of risk has been characterized in terms of the probability that a rail defect will result in a derailment. With this approach, risk has been "defined" as 0.13 percent of all rail defects (service and detected combined) or 0.5 percent of service failures alone. Thus the higher level of risk is associated with service defects, those not found by rail testing, which supports the use of rail testing to reduce risk and minimize derailments.

Inadequate or infrequent testing can result in the development of excessive service defects. Excessive testing is expensive and disruptive to traffic, resulting in train delays and loss of capacity. The "optimum" test interval must be defined from the points of view of safety and economics. This inspection interval (or the time between tests) is dependent on rail condition, defined in terms of defect history and traffic level.

Increases in defect rate necessitate a decrease in inspection interval. Exhibit 3 presents this concept from a risk perspective. Noting that the number of fatigue defects in rail will increase as the rail accumulates tonnage, a fixed inspection interval (Exhibit 3A) will result in an increase in defects found per inspection cycle. Decreasing the inspection interval as the rail accumulates tonnage can keep the level of defects found per inspection constant (Exhibit 3B). Thus, coordinating inspection interval with the age and



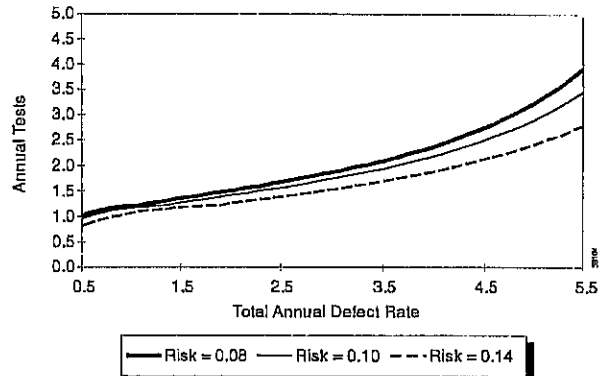
**Exhibit 3. Comparison of Alternate Inspection Strategies**

defect history of the rail and reducing inspection interval as the rail develops increased levels of defects can serve to control risk at an acceptable and constant level.

In order to schedule rail tests, railroads make use of a range of scheduling formulae. These formulae include sensitivity to such key parameters as:

- Recent defect history (service defects, detected defects, and total defects)
- Rail condition/age
- "Bad" rail heats
- Track class/speed
- Track condition
- Rail section
- Annual tonnage density
- Traffic type
- Presence of passenger trains
- Presence of hazardous materials

Current North American railroad practice is to operate a test vehicle until only those defects are found that can be handled by the rail-replacement crew following the car. Once these defects are found,



**Exhibit 4. Annual Test Requirements vs. Defect Rate; Sensitivity to Risk**

the testing is stopped until the rail-replacement crew catches up. This practice limits daily productivity to 10 to 20 miles per day. Improving this productivity is being addressed by:

- Use of waivers to provide a time delay between detection and repair action,
- Improving technology to increase reliability (reduce false alarms) and increase test speed, and,
- Improving replacement practices (e.g. higher performance gangs) to improve the rate of defect replacement.

One waiver currently in place permits a five-day delay in the repair of non-critical defects and offers the possibility of improving test-car productivity, reducing cost, and allowing for a higher level of testing effectiveness.

#### ACKNOWLEDGMENTS

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