GROUP	E
EXHIBIT	
13	

NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Norfolk Southern Railway general merchandise freight train 32N derailment with subsequent hazardous material release and fires, in East Palestine, Ohio, on February 3, 2023

Agency / Organization

Federal Railroad Administration

Title

Exhibit 13-MPEComplianceManual2013 Chapter 16

Chapter 16

Wayside Detector/Train Inspection Guidance

AAR and Class I Railroad Initiatives

To reduce or mitigate the adverse effects of heavy axle loads on track infrastructure, degradation of freight car components and as tools for enhanced train inspections, the railroads have started leveraging the emerging wayside detection technology. Besides addressing the higher or distressed-and-unsafe “stress state” of equipment and track, the railroads intend to achieve, at a minimum, an equivalent or enhanced level of railroad safety by using the wayside detection technology. To achieve this goal, the Advanced Technology Safety Initiative (ATSI) was implemented on October 1, 2004 by the Association of American Railroad’s (AAR’s) Technical Services Working Committee. ATSI is a predictive and proactive maintenance system that uses the best available technology to detect and report potential safety problems and poorly performing equipment before they result in accidents or undue rail damage.

The overall objectives of the railroads are to enhance the quality, efficiency and safety of the train inspection processes through this technology including any assessment of the underlying causal issues. It is believed that a mature wayside detector system can provide remote intervention capabilities by combining facets of this technology that relate to the prevention of incidents, detection of incidents, notification of incidents and recovery from incidents.

Under the auspices of the AAR, the Class I railroads and private car owners have already embarked upon technology driven train inspections. There are a variety of wayside detectors (over 130) already deployed throughout the U.S. and the deployment list is rapidly growing. The initial objective of this undertaking was to reduce the “stress state” of the railroads, that is, to fix or remove from revenue service problematic equipment (poorly performing and defective equipment) before it severely damaged the track infrastructure. That is, the “predictive and proactive maintenance system” of in-service equipment is to identify the component’s deteriorating performance through different levels of degradation to the final level, at which time operations must be interrupted to mitigate the condition. The concept consists of successive “triggers” to indicate progressive degradation and preventive action(s) to be taken.

The wayside detector technologies consist of three general categories: wayside performance detection, machine vision and wayside condition detection. Under the ATSI initiative all of these technologies will eventually feed the Transportation Technology Center Incorporated’s (TTCI’s) Integrated Railway Remote Information Service (InteRRIS®) system, which will then feed the “sorted” data into the Equipment Health Monitoring System (EHMS) at the Railinc. Railinc, which is AAR’s IT provider headquartered at Cary, North Carolina, then generates equipment alerts to the car owners through the EHMS.

Table 1: Detector Locations by Railroad, City and State

Type	Railroad	City	State
TPD	FAST-TTC	Pueblo	CO
TPD	BNSF	Argyle	IA
TPD	BNSF-Track 1	Argyle	IA
TPD	BNSF-Track 2	Argyle	IA
TPD	BNSF	Victorville	CA
TPD	BNSF	Chriesman	TX
TPD	BNSF	Sandpoint	ID
TPD	BNSF	Joppa	MT
TPD	BNSF-Track 1	Ludlow	CA
TPD	BNSF-Track 2	Ludlow	CA
TPD	BNSF	Trinidad	CO
TPD	BNSF	Flagstaff	AZ
TPD	BNSF	Nonpareil	NB
TPD	BNSF	Pomona	MO
TPD	BNSF	Maupin	OR
TPD	BNSF	St. Croix	WI
TPD	CSXT	Carfax	VA
TPD	FEX	La Piedad	MX
TPD	FXE	Nazareno	MX
TPD	NS	Eggleston	VA
TPD	NS-Track 1	Science Hill	KY
TPD	NS-Track 2	Science Hill	KY
TPD	UP	Evanston	WY
TADS	BNSF	Antioch	NE
TADS	BNSF	Kingman	AZ
TADS	BNSF	Velox	WA
TADS	CP	Arnold	BC
TADS	CSXT	Hague	GA
TADS	NS	Flat Rock	KY
TADS	UP	Martin Bay	NE
WILD	AMTK-Track 2	Edgewood	MD
WILD	AMTK-Track 3	Edgewood	MD
WILD	AMTK-Track 1	Mansfield	MA
WILD	AMTK-Track 2	Mansfield	MA
WILD	BNSF-Track 1	Atherton	MO
WILD	BNSF-Track 2	Atherton	MO
WILD	BNSF-Track 1	Bagdad	CA
WILD	BNSF-Track 2	Bagdad	CA
WILD	BNSF-Track 1	Bingham	NE
WILD	BNSF-Track 1	Bismarck	ND
WILD	BNSF-Track 1	Cochrane	WI
Type	Railroad	City	State
WILD	BNSF-Track 2	Cochrane	WI
WILD	BNSF-Track 1	Kirkland	TX
WILD	BNSF-Track 1	Mesa	WA
WILD	BNSF-Track 1	Peshastin	WA
WILD	BNSF-Track 1	Denver	CO
WILD	BNSF-Track 1	Seymour	MO
WILD	BNSF-Track 1	Wheatland	WY
WILD	BNSF-Track 1	Winton	CA
WILD	CN-Track 1	Aldershot	ON
WILD	CN-Track 2	Aldershot	ON
WILD	CN-Track 3	Aldershot	ON
WILD	CN-Track 1	Moncton	NB
WILD	CN-Track 1	Winnipeg	MB
WILD	CN-Track 1	Arnold	BC
WILD	CN-Track 1	Sainte-Helene de Bagot	QC
WILD	CN-Track 1	Bentonia	MS
WILD	CN-Track 1	Winnipeg	MB
WILD	CN-Track 2	Winnipeg	MB
WILD	CN-Track 1	Cedars	QC
WILD	CN-Track 2	Cedars	QC
WILD	CN-Track 1	Dugald	MB
WILD	CN-Track 1	Dubuque	IA
WILD	CN-Track 1	Neenah	WI
WILD	CN-Track 1	Melville	SK
WILD	CN-Track 1	Jasper	AB
WILD	CN-Track 1	Vinsulla	BC
WILD	CN-Track 1	Hornepayne	ON
WILD	CN-Track 1	Sioux Lookout	ON
WILD	CN-Track 1	Prince George	BC
WILD	CN-Track 1	Nattress	MB
WILD	CN-Track 1	Nechako	BC
WILD	CN-Track 1	Williams Lake	BC
WILD	CN-Track 1	Edmonton	AB
WILD	CN-Track 1	Waukesha	WI
WILD	CN-Track 1	Grand Mere	QC

WILD	CN-Track 1	Stony Plain	AB
Type	Railroad	City	State
WILD	CN-Track 1	Capreol	ON
WILD	CN-Track 1	Uncas	AB
WILD	CN-Track 1	Zephyr	ON
WILD	CN-Track 1	Vinsulla	BC
WILD	CN-Track 1	Winnipeg	MB
WILD	CN-Track 1	Battle Creek	MI
WILD	CN-Track 1	Champaign	IL
WILD	CP-Track 1	Calgary	AB
WILD	CP-Track 1	Toronto	ON
WILD	CP-Track 1	Calgary	AB
WILD	CP-Track 2	Calgary	AB
WILD	CP-Track 1	Minneapolis	MN
WILD	CP-Track 1	Golden	BC
WILD	CP-Track 1	Moose Jaw	SK
WILD	CP-Track 1	Toronto	ON
WILD	CP-Track 1	Moose Jaw	SK
WILD	CP-Track 1	Winnipeg	MB
WILD	CP-Track 1	St. Paul	MN
WILD	CP-Track 1	Montreal	QC
WILD	CP-Track 1	Sudbury	ON
WILD	CP-Track 1	Thunder Bay	ON
WILD	CSX-Track 1	Cartersville	GA
WILD	CSX-Track 1	Grafton	OH
WILD	CSX-Track 2	Grafton	OH
WILD	CSX-Track 1	Johnson City	TN
WILD	CSX-Track 1	Lowell	WV
WILD	CSX-Track 1	Middlesex	NJ
WILD	CSX-Track 1	Pendleton	IN
WILD	CSX-Track 2	Pendleton	IN
WILD	CSX-Track 1	Springfield	PA

WILD	CSX-Track 2	Springfield	PA
Type	Railroad	City	State
WILD	CSX-Track 1	Walthourville	GA
WILD	CSX-Track 1	Self Creek	AL
WILD	FEC-Track 1	Miami	FL
WILD	FXE-Track 1	Corralejo	GT
WILD	FXE-Track 1	Sauz	CH
WILD	NS-Track 1	Knoxville	TN
WILD	NS-Track 1	Marietta	PA
WILD	NS-Track 2	Marietta	PA
WILD	NS-Track 1	Altoona	PA
WILD	NS-Track 2	Altoona	PA
WILD	NS-Track 1	State Line	IA
WILD	NS-Track 1	South Bend	IN
WILD	NS-Track 2	South Bend	IN
WILD	NS-Track 1	Waverly	VA
WILD	NS-Track 2	Waverly	VA
WILD	UP-Track 1	Chamberlin	TX
WILD	UP-Track 1	Donaldson	AR
WILD	UP-Track 1	Elton	LA
WILD	UP-Track 1	Fields	OR
WILD	UP-Track 1	Gothenburg	NE
WILD	UP-Track 2	Gothenburg	NE
WILD	UP-Track 1	Martin Bay	NE
WILD	UP-Track 1	Millican	TX
WILD	UP-Track 1	East Peru	WY
WILD	UP-Track 2	Red Desert	WY
WILD	UP-Track 1	Stuttgart	AZ
WILD	UP-Track 1	Sunset	CA
WILD	UP-Track 1	Westvaco	WY
WILD	UP-Track 1	Wister	CA

InteRRIS® is a data warehouse, accessible through the Internet. It is designed to assemble and integrate data from all types of devices that monitor vehicle performance and return

added value to its users by giving quantitative evaluations of rail vehicle performance by enabling planned maintenance and monitoring post maintenance performance to provide quality control checks on the maintenance performed. Railinc located in Cary, North Carolina is the industry's largest and most accurate source for real-time interline rail data. Railinc maintains Industry Reference Files (IRFs) and Umler data. Umler is the electronic resource that contains critical data for North American transportation equipment depicting list of all nationwide fleet by car initials and numbers and specific car data. Railroads, equipment owners, agents, shippers, ports, suppliers, industry consultants, government agencies and car maintenance facilities are all users of Umler.

The first effort under this new initiative is the use of data from Wheel Impact Load Detectors (WILD) to monitor the health of in-service railcar wheels. When a freight car wheel exerts a peak impact load of 90 kips or above as measured by a WILD site, it is not operating effectively, is considered "out of round" and on the path to failure. The program provides a window of opportunity that opens when a wheel reaches a peak impact load of 65 kips. The very first WILD detectors started appearing at Conrail in the early 1990's to protect against flat wheel impacts on concrete ties. It appears that WILD technology has been quite useful in indicating progressive component degradation using successive wheel impact load thresholds as "alert" levels (see WILD description later).

Future Considerations for Wayside Detectors

FRA encourages the use of new technology when appropriate. FRA's mission is to promote railroad safety. To carry out this mission, FRA enforces Federal safety standards. The safety standards are tailored to the technology that exists at the time that they are promulgated. Often, new technology can be used in conjunction with existing technology to enhance safety. Railroads are also increasingly using wayside detection technology and their embedded event recorders to assess the cause(s) of train accidents and derailments. This information can also be helpful to FRA during an accident or derailment investigation. The following is a list of common wayside detector features:

- Data-driven tools for railways, vehicle owners, vehicle builders, vehicle maintenance, and component manufacturers,
- Products that monitor performance from wayside,
- Capabilities for the user to make predictive, condition-based rather than reactive vehicle maintenance decisions,
- Automation of communication processes,
- Car owner access to equipment to intervene and effect predictive maintenance strategy,
- Improved maintenance planning and scheduling for proactive management of component life cycle and optimized/ scheduled vehicle repair,
- Automated maintenance inspection for improved reliability of measurements, reduced need for manual inspection, and finding defective car/ truck components,
- Improved safety,
- Improved utilization of car fleet,
- Reduced damage to track and lading,
- Capability to cross reference data and produce more efficient gains,
- Supplements current inspections and adds to network efficiency,
- Networking and management of detector data from all railroads,
- Continuous updates of inspection record of each car for critical running gear performance,

- Interchange data with other railroads/ car owners in advance of car interchange,
- Enhancement of line-points with automated in-coming lineup of workload by defining predictive workload, providing easily viewed and printed workload for in-coming trains/ cars, speeding up normal visual inspections by targeting only problem cars, and extending interval between conventional visual inspections,
- Enhancement of railroad and car-owner “mechanical desk” knowledge of car “health warnings” by using continuous and automated electronic form to spell out symptoms for preventive action, directing maintenance to least disruptive time in the car cycle, using trend analysis to optimize maintenance cycle, and instructing special attention and handling for problem cars, and
- Verification, accountability and ability to audit.

Waiver(s) Issued

Notably, the Union Pacific Railroad (UP) recently applied and was granted relief from single car air brake tests (SCABTs) on empty cars utilizing defect information on irregular wheels and defective bearings gathered by wayside detectors such as WILD, ABD, HBD, HWD, WPM, WPD or TAD. This relief involves empty cars at UP’s North Platte, NE, facility wherein replacement of “non-FRA-condemnable” wheel sets with minor defects that are condemnable under AAR standards is ongoing per UP’s in-train wheel set replacement program as a preventive maintenance tool. A copy of the Safety Board approval letter, dated January 16, 2009, granting this waiver of compliance from Title 49 CFR § 232.305(b)(2) is located in Appendix B. For further details on this waiver, see FRA Docket Number FRA-2007-28454.

Wayside Detector Glossary of Terms

To better understand the nomenclature and “language” of wayside detectors currently used throughout the U.S. a glossary of terms has been provided below:

- **ABD:** Acoustic Bearing Detector. Measures acoustic signatures, indicates bearing defects, and signifies derailment prevention.
- **AISC:** Automated Inspection of System Components.
- **AOA:** Angle of attack of a wheel set is defined as the angle between the track radial line and the center line of the wheel set’s axle. It is a measure of the lateral creepage and lateral loads exerted on the track. It indicates the dynamic behavior and curving performance of the bogie. High value indicates a vehicle with defects and potential for wheel climb derailment.
- **ASAIS:** Automated Safety Appliance Inspection System. Measures dimensions, detects missing appliances and compares standards; and signifies set-out performance.
- **BOJ:** Burnt-off Journal results when a roller bearing overheats and seizes. This condition generally results in missing a portion of the affected axle. The axle journal along with the associated bearing may be discolored and completely separated from the rest of its wheel set.
- **Broken Rail Detection:** Acoustic method or fiber optics or strain gages or track circuit. Signifies derailment prevention from broken rail.

- **BSM:** Brake Shoe Module. Measures thickness and missing parts using video machine vision, indicates brake shoe defects, and signifies damage prevention.
- **CAD:** Cracked Axle Detector. Uses laser to generate surface waves along the length of the axle, measures amplitudes of generated waves by air coupled ultrasonic transducers, detects cracks as reflected waves by signature cracks; signifies derailment prevention.
- **CWD:** Cracked Wheel Detector. Uses laser-Air Hybrid Ultrasonic Technique (LAHUT) to create surface and body waves in the wheel which are then recorded using air-coupled ultrasonic transducers. Modification of waves by reflection and refraction at the crack is then detected as a combination of peaks in the frequency domain; signifies derailment prevention.
- **DED:** Dragging Equipment Detector. Signifies damage and derailment prevention.
- **HBD:** Hot Box Detector. Measures temperature change, indicates roller bearing defects, and signifies derailment prevention.
- **HWD:** Hot/Cold Wheel Detectors. Measures wheel temperature, indicates airbrake system defects, and signifies brake performance.
- **IAM:** Inter-axle misalignment is the internal misalignment between the two wheel sets in a bogie, and is measured as the AOA of the leading wheel set minus the AOA of the trailing wheel set. IAM measures the dynamic performance such that a higher value indicates a vehicle with defects.
- **LAD:** Low Air-hose Detector. Measures air-hose height above rail using video machine vision, indicates coupler/air-hose defects, and signifies train stop performance.
- **OILD:** Overload/Imbalance Load Detector. Measures wheel load imbalance using WILD weigh-in-motion, indicates shifted loads, and signifies curving performance and derailment prevention.
- **Rail Flaw Detection:** Laser based ultrasonic NDT. Signifies damage prevention of rails with flaws.
- **TAD:** Trackside Acoustic Detector. Measures acoustic signatures, indicates roller bearing defects, and signifies derailment prevention.
- **TBOGI:** Truck/Bogie Optical Geometry Inspection. Measures geometric faults in the alignment and tracking of bogie wheel sets using laser/optical means, indicates bogie performance deficiencies, and indicates set-out performance.
- **TE:** Tracking error is the lateral distance between the center lines of the axles in the bogie and is defined as the tracking position of the leading wheel set minus the tracking position of the trailing wheel set. A higher value of the TE also represents a degraded dynamic performance of the vehicle.
- **THD:** Truck Hunting Detector. Measures lateral instability in terms of poor lateral dynamic performance, indicates truck and suspension defects, and signifies derailment prevention.
- **TP:** Tracking is defined as the center line of the wheel set compared to the track center line. This is an interim parameter which is used to define the Tracking Error (TE) of a bogie.
- **TPD:** Truck Performance Detector. Measures lateral/vertical wheel loads and angle of attack (AOA), indicates truck and suspension defects based on curving

performance, and signifies derailment prevention.

- **TS:** Thermal Scan. Using thermal sensors detects heat generated at the interface between the brake shoe and the wheel to determine brake application, is a complement to BSM to assess brake shoe condition, and signifies damage prevention.
- **WBT:** Warm Bearing Trending. Measures bearing temperature between detectors and identifies excessive trends.
- **WILD:** Wheel Impact Load Detector. Measures impact loads, indicates wheel tread defects, and signifies damage prevention.
- **WPM or WPD:** Wheel Profile Module or Wheel Profile Detector. Measures wheel profile dimensions using laser/video scanners, indicates wheel rim/tread shape defects, and signifies set-out performance.
- **WTT:** Wheel Temperature Trending.

Wayside Detector Treatise

There are three aspects of wayside monitoring of a railway vehicle: 1) its present condition and required maintenance, 2) detection and diagnosis of developing faults, and 3) trending for future performance for preemptive, preventive and proactive maintenance strategies. In this context, the wayside detectors are of two types, reactive systems and predictive systems. Reactive systems detect actual faults on the vehicles. Generally the information from reactive systems is not suited for trending, but is of importance to protect the equipment from further damage due to the fault. Some examples of reactive detector technology are the DED, HBD and HWD. Predictive systems, on the other hand, are capable of measuring, recording and trending the ride performance of the vehicles and also specific components. From the collected information it is possible to analyze the condition of the equipment to predict possible failures and faults that may occur in a near or distant future. This makes it easier to plan the maintenance activity ahead and also to utilize the equipment in a more efficient way. Some examples of predictive detector technology are the ABD, TPD, T/BOGI, THD, TAD, WILD, WPM, WPD, AISC, ASAIS, and BSM.

- **Wheel Impact Load Detector (WILD)**

  WILD is an electronic data collection device that measures vertical wheel forces (impacts from damaged wheels as shown in **Figure 1**) on the rail via rail mounted strain gages. It consists of a system of strain gauges placed on the web of the rail, as shown in **Figures 2** and **3**, to measure rail deformation under traffic. It measures impact forces caused by flat, shelled, spalled, out-of-round, built-up-tread and damaged wheels. The high impact forces damage vehicles, cargo, and infrastructure. Preemptive reduction of high impact forces by truing faulty wheels and removing damaged wheels entails benefits due to reduction in derailments, rail fatigue, bearing damage, cold weather rail fractures, car and truck damage, concrete tie cracking and wood tie plate cutting; and increment in wheel tread life and fuel efficiency.

Figure 1: A Damaged Wheel

Figure 2: A Typical Strain Gage Installation on Rail Web over a Crib

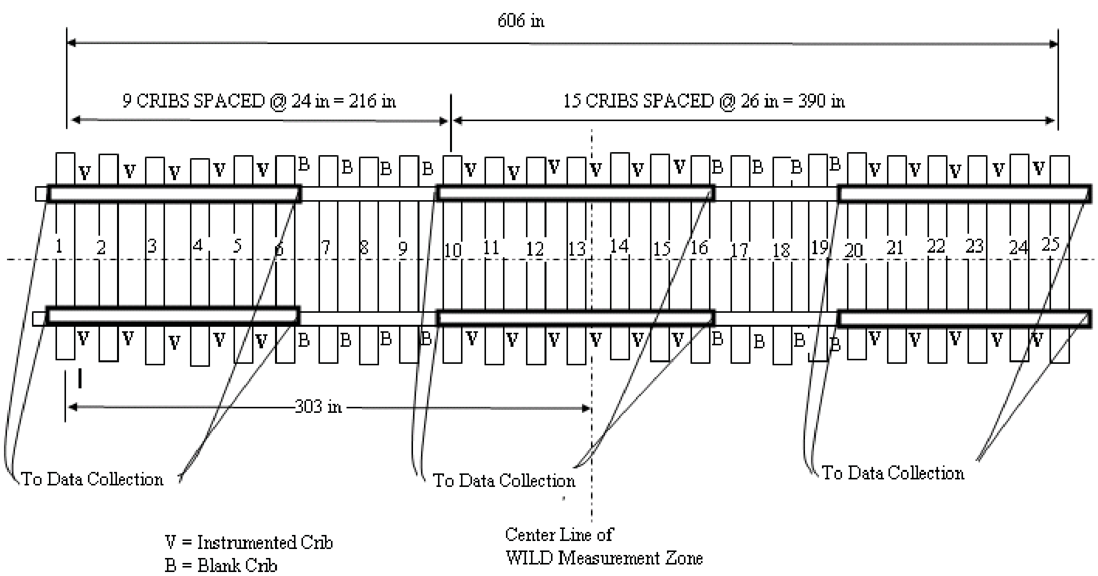


Figure 3: A Typical Layout of WILD Measurement Site

The various features of WILD detectors, **Figure 4**, may include: impact force monitoring, train-vehicle-wheel information, bi-directional traffic, automatic car counting and identification (with valid car library), self-diagnostics, instrumentation layout optimization for fleet wheel diameters, and AAR Rule 41 Standard compliance. The corresponding measurements may include: car IDs, wheel IDs, nominal, peak and dynamic wheel loads, axle loads, train speed and length, tonnage (by train, week and month).

The data collected by the WILD detector network in the U.S., Canada and Mexico resides in the Equipment Health Management System (EHMS), which is the AAR approved reference file maintained by Railinc (www.railinc.com). The various thresholds, per AAR's Field Manual, indicating progressive component degradation are as follows:

1) WILD-reading of 65 kips to less than 80 kips for a single wheel indicating an *appropriate* maintenance/ repair attention, termed as the "Window of Opportunity" alert level requiring issuance of *first* Maintenance Advisory from EHMS;

2) WILD-reading of 80 kips to less than 90 kips for a single wheel indicating a *warranted* maintenance/ repair attention, termed as the "Opportunistic Repair" alert level requiring issuance of *second* Maintenance Advisory from EHMS;

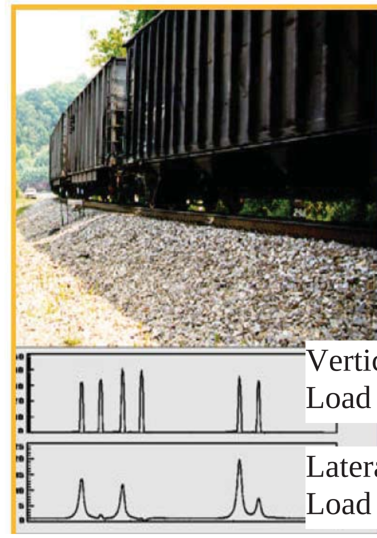
3) WILD-reading of 90 kips to less than 140 kips for a single wheel indicating an *urgent* maintenance/ repair attention, termed as the "AAR Condemnable" alert level requiring issuance of *third* Maintenance Advisory from EHMS; and

4) WILD-reading of 140 kips or greater for a single wheel indicating *required* maintenance/ repair, termed as the "Final Alert" level resulting in the issuance of *fourth* Maintenance Advisory from EHMS.

Figure 4: A Typical WILD Deployment on Revenue Track indicating Instrumented Rail over Cribs

- **Truck Performance Detector (TPD)**

  TPD detectors monitor the response of car's suspension system along curved track to signal worn or defective component conditions. Conditions detected by TPD are truck warp, poor steering, hollow worn wheels and poor wheel load equalization. Detection of these ailments adds to the security against derailments. TPDs measure wheel/rail forces (vertical and lateral) via strain gauge sensors on the rails in selected reverse curves, **Figure 5**. They also measure the angle of attack (AoA – the angle taken by the axle relative to the direction of motion) of each axle with respect to the rail, which in combination with measured vertical and lateral forces provides information regarding the steering capability of the truck through curves. TPDs identify suspension systems that do not perform optimally in (or after negotiating) curves. Poor performance may result in derailments due to wheel climb, gauge spreading, rail rollover or track panel shift. Poor performance also contributes to wear on rail, special track work, wheel profiles and flanges. By identifying poor performers through performance-based monitoring, preventive maintenance can be performed, reducing derailment risks and improving the overall safety of rail operations.



Flange Climb → High L/V and AoA;
Warped Truck → High AoA;
Track Panel Shift → High NAL (Net Axle Load);
Rail Roll Over → High TSLV (Truck Side L/V)

Gage Spreading → High L
Wheel Unloading → Low V
Track Damage → High V

Figure 5: A Typical TPD Deployment on Revenue "S-Curve" Track Showing Vertical and Lateral Load (Collected) Data, and Indicating the Outcome of Their High Magnitudes

A typical TPD site may consist of an "S" curve arrangement where two curves (typically 4 to 6 degrees) are in the opposite direction relative to each other (i.e., a right-hand and a left-hand curve with a tangent section separating them) as shown in **Figure 6**. This gives the possibility to collect data on the vehicles behavior in both right and left curves as well as in the tangent track.

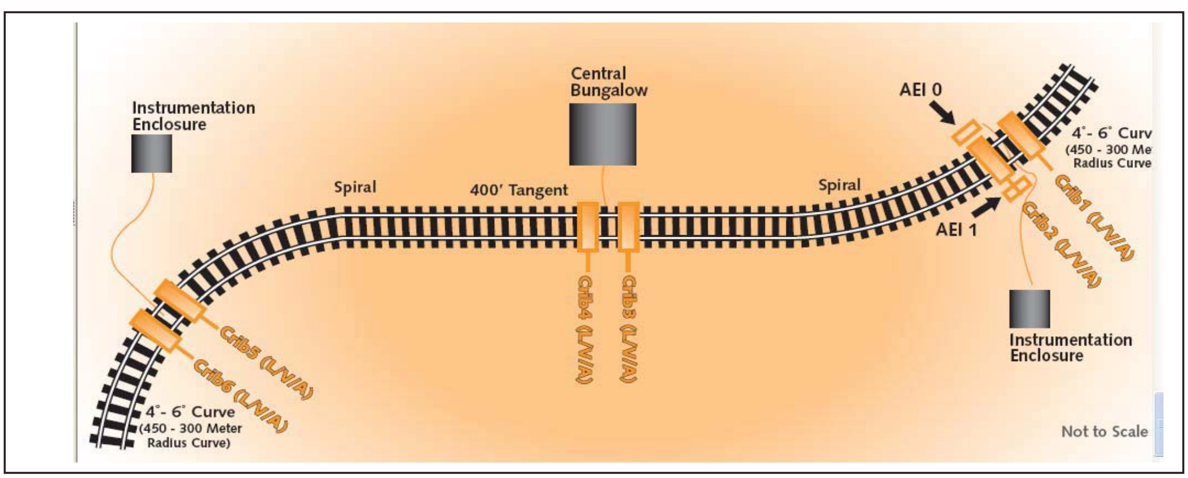


Figure 6: A Schematic Showing the "S-Curved" Track and Location of Instrumented Cribs

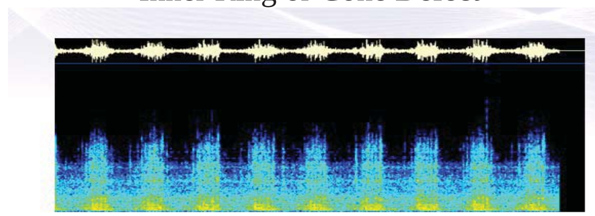
TAD wayside detectors monitor bearings by automatically detecting flaws in wheel bearings by evaluating the acoustic signature of the noise (1 kHz and above) created by the flaw, **Figures 7 and 8**, before the bearing becomes hot or seizes in service and results in accidents due to burned-off roller bearings. The most problems in roller bearings occur due to flaws such as cup spalls; cone spalls; spalled, etched, seamed rollers; water etched raceways; and spun or loose cones. Arrested center plate rotation, defective side bearings, and hollow tread wheels add to the roller bearing woes. TADs can detect symptoms of bearing failure at a much earlier stage than hot box detectors (HBDs), and can spot flaws that a visual inspection may not detect. The TAD detectors may find internal roller bearing defects, long before a hotbox detector will detect the problem and so avoid possible derailments with the inevitable consequences of cost, safety, disruption to the network.

TAD wayside detectors use an optimized array of microphones located on each side of the track, **Figure 9**. The microphones are spaced vertically and horizontally. The microphones simultaneously record signals and sensors identify each wheel of the passing train. The acoustic signals are analyzed over a wide range of frequencies. Since roller bearing flaws create noise – they produce an acoustic signature. The data is analyzed to ascertain the presence or absence of these signatures. Trains pass the TAD detector sites at 30 to 50mph.

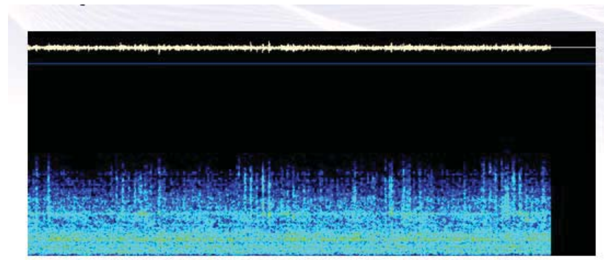
These detectors are used to mitigate failures, determine high risk bearings and identify severest defects using growler software. AAR has developed Rule 36A.3.c Cause for Removal (AAR Field Manual) for industry. This detection pertains to reducing burn-off derailments. It can be used for customized alarming for the high risk bearings and correlating hot bearings setouts with acoustic alarms.

Figure 7: Damaged Cups and Cones of Bearings

Inner Ring or Cone Defect



Roller Defect



Outer Ring or Cup Defect

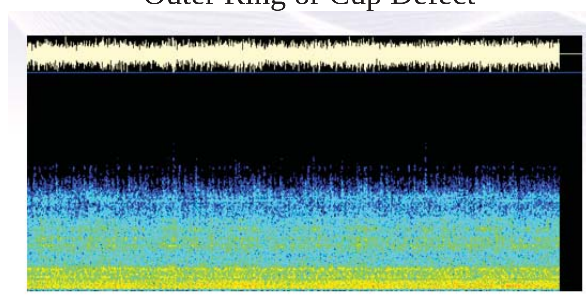


Figure 8: Sound Signatures of Defects

Figure 9: A Typical TAD Site in Revenue Service consisting of Microphone Array, Wheel Sensors and AEI

- **Low Air-Hose Detector (LAD)**

Rail car braking systems depend upon the operational integrity of the coupling hoses that connect air pipes. By design, if a coupling hose fails or becomes otherwise uncoupled, a moving train is put into an emergency braking condition. Unintentional de-coupling can and does occur due to low-lying hoses, **Figure 10**, hitting obstructions in the roadbed. At a minimum, the resulting emergency stop causes delays, but may also damage wheels by creating flat spots and damage lading. The current solutions to this problem incorporate a non-contact, optical sensing approach.

Using infrared light curtains (sensors) to visually inspect each air hose, the Low Air-Hose Detector measures the distance between the top of rail and bottom of each hose, **Figure 11**.

Figure 10: Air Hose State in a Train

Figure 11: A Typical Low Air-Hose

This examination is performed only in the appropriate area between vehicles to minimize the possibility of false alarms. It then identifies the leading and trailing tags nearest each hose that lies below user defined thresholds. The Low Air-Hose Detector integrates AEI tag readers to provide a complete record of offending vehicles, so corrective action can be taken at the most convenient location.

- **Truck Hunting Detector (THD)**

Hunting trucks underneath rail cars can violently oscillate, **Figure 12**, from one rail to the other as they traverse along tangent track, inducing excessive lateral forces that significantly contribute to the rapid wear of rail and rail cars in a relatively short time. In the worst case, such hunting may lead to vertical wheel unloading and wheel climb derailment. Also, this particular type of degraded vehicle performance is a leading cause of damage to delicate lading. At a minimum, hunting trucks cause increased fuel consumption. Unchecked, severe damage to truck components and derailment can result.

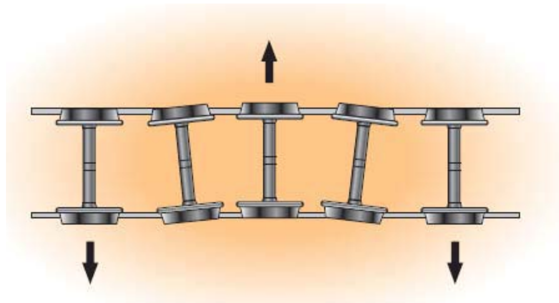


Figure 12: Lateral Displacements of an Axle in Hunting Truck

By measuring the lateral instability that indicates truck and suspension defects, THD wayside detectors, **Figure 13**, can be used to identify inspection and maintenance procedures for bad acting cars to reduce derailments due to flange climb. The hunting data collected by TTCI was used to confirm both the hunting conditions and the condemnable defects. The representative cars at various levels of hunting performance were sent to TTCI for inspection, test, teardown and repair. The teardowns showed that the suspect cars had worn truck components, couplers & coupler carrier plates and door mechanisms. Also, these cars showed signs of either (or both) 1) low truck warp restraint (high/worn wedges/ column wear liners) and 2) low truck/ car body rotational constraint (no constant contact sides bearings (CCSBs), no CCSB preload, melted or damaged CCSBs.) This data consisting of approximately 300 cars/year with a hunting index (HI) > or = 0.65 and approximately 450 cars/year with a hunting index (HI) > or = 0.50 in a 12-month period confirmed that a car with either of the above noted hunting indices was condemnable at any time. As such, the car hunting condemnable indices (two HI readings above 0.50 in a twelve month period or a single HI reading above 0.65) were then implemented as new AAR interchange rule on July 1, 2006, and were adopted in the AAR Field Manual Rule 46.

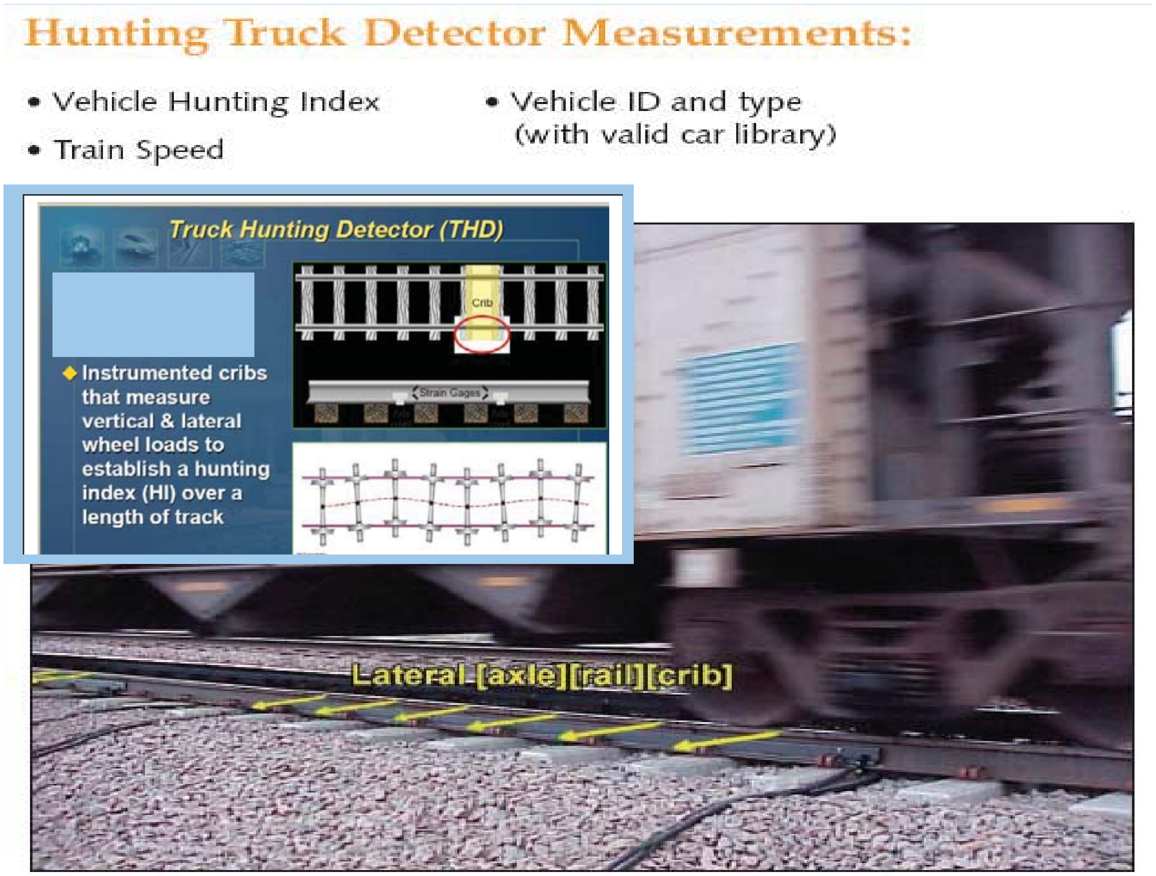


Figure 13: Typical THD Deployment on Revenue Track Indicating Instrumented Cribs

Similar in design to the wayside Wheel Impact Load Detector (WILD), THD wayside detectors can reside at the WILD detector locations. This add-on capability provides measurements of both the array of lateral forces, by the THD, exerted by a hunting truck on a passing train and the simultaneous readings of vertical forces from the WILD. As such the dynamic relationship between vertical and lateral forces is fully accounted to identify those critical instances where the wheel flange and rail gage face geometry may promote flange-climb derailments. These measurements are transformed into the “hunting index” to identify excessive side-to-side motion of bad acting cars.

Some empty or lightly loaded cars are susceptible to truck hunting when operated at speeds over approximately 50 mph. In order to reduce the severity of truck hunting, trucks can be equipped with features such as constant contact side bearings, center plate extension pads, hydraulic snubbers or frame bracing. The restoration of worn truck components also mitigates truck hunting.

- **Hot Box Detector (HBD)**

The function of hot box detectors is to detect overheated journals. Overheated roller bearings occur when inadequate lubrication or mechanical flaws result in an increase in bearing friction. This phenomenon is called a "hot box" in railway jargon. The bearing temperature can continue to rise and lead to complete failure of the axle, commonly referred to as a "burnt-off journal" (BOJ). A BOJ normally results in the derailment of the car on which it occurs. Should axle failure happen while the train is proceeding at a high speed, the derailment frequently results in multiple cars derailed and/or damaged. A hot box condition on roller bearing-equipped rail cars can elevate quickly and become a BOJ within a few miles.

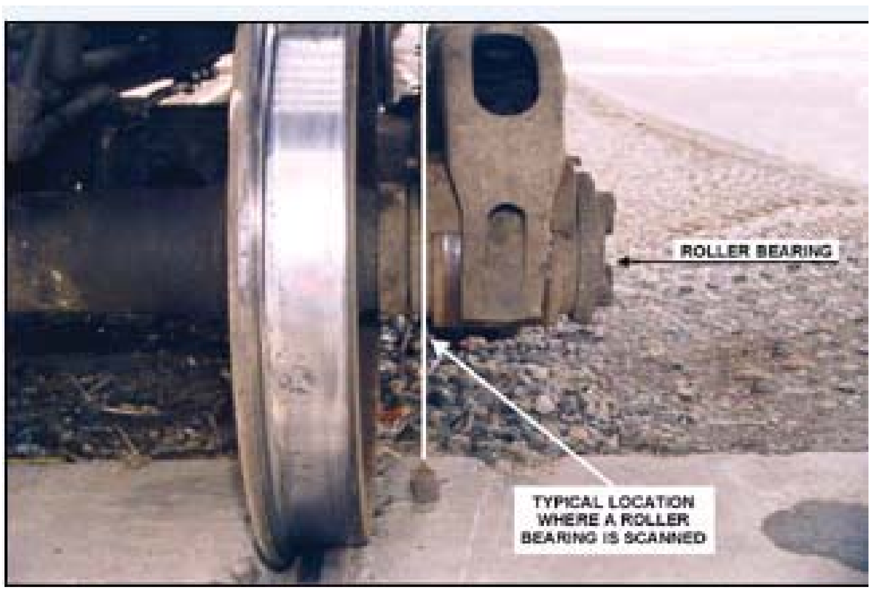


Figure 14: Typical Location for Scanning a Bearing

The HBD senses radiant infrared heat energy emitted from the bearing as it passes over the detector scanner, **Figures 14** and **15**. The heat energy is converted to an electrical output proportional to the amount of heat and relative to the ambient temperature. Ambient temperature is determined by scanning the bottoms of the rail cars as they pass. Data is then processed to “warm” and “hot” levels. If the amount of energy sensed by the HBD exceeds preset values, then the appropriate action is warranted.

The HBDs are rated to work in ambient temperatures. Severe environmental conditions, such as snow storms and blowing snow conditions, heavy rain and ice, can affect the quality of the scan data. The type of housing used for the roller bearings within the truck assembly can have an impact on the ability of the scanners to sense infrared heat energy.

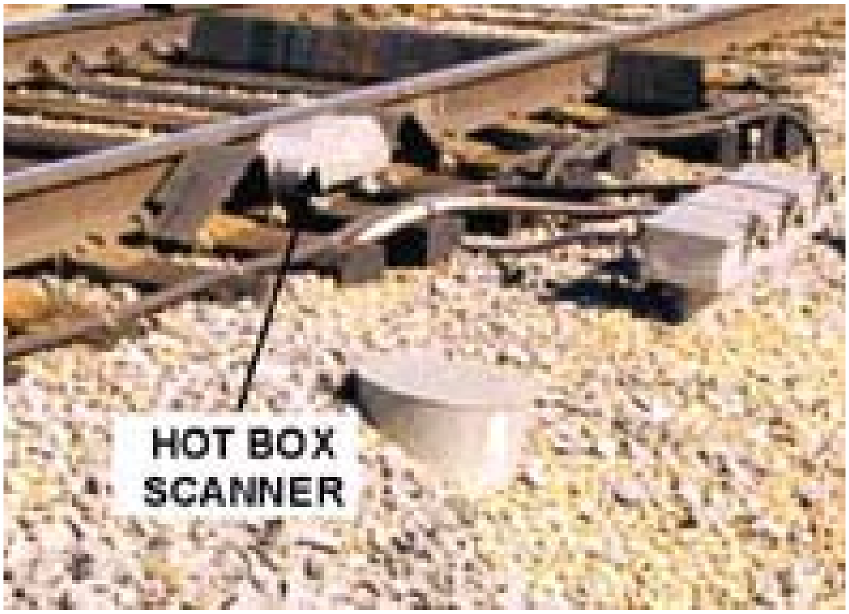


Figure 15: Typical Location of Hot Box Scanner on Field Side of Track

- **Dragging Equipment Detector (DED)**

  The dragging equipment detector detects any object hanging under a car or locomotive. The DEDs may be of two different designs; paddle (mechanical) style, **Figure 16**, or impactor (electronic) style, **Figure 17**. The paddle style consists of strike plates, both

Figure 16: Paddle style DED

Figure 17: Impactor style DED showing location of an accelerometer on the underside of the strike plate

inboard and outboard of the rails, attached to a shaft with a cam-operated switch and a return spring. An object striking the paddles in either direction would rotate the shaft, momentarily opening the switch contacts. An open circuit would trigger an alarm. The impactor style is designed to alleviate the problems associated with the paddle style under deep snow conditions and has no moving parts. Stationary strike plates between and outboard of the rails are fitted with accelerometers which detect impact energy. Sufficient impact energy creates an electrical output that generates an alarm.

- **Hot Wheel Detector (HWD)**

The function of hot wheel detector is to detect overheated wheels. Abnormally high temperatures indicate brake pads stuck to wheel treads. This condition causes a significant increase in friction resulting in hot wheels indicating brake problems. The HWD is similar to the HBD in that it senses radiant heat energy using infrared scanner technology. However, the target in this instance is the wheel plate area near the tread, approximately 2 1/2 inches above the rail, **Figure 18**. Some systems use an HWD scanner on both sides of the track, but most use only one scanner on one side of the track. When only one HWD scanner is used, **Figure 19**, to scan wheels on both the near and far rail, it is normally set at an angle to the track. The outboard wheel plate surface of a wheel on the near rail can be scanned, as can the inboard wheel plate surface of a wheel on the far rail. A reference temperature is established by placing a white board on the far side of the track opposite the HWD scanner. The reference board is used as a base value in order to produce semi-absolute wheel plate temperature readings. These readings are then compared to preset alarm thresholds.

If a wheel is cold during brake application, e.g., in a run going down the grade, then its brakes are not working correctly.

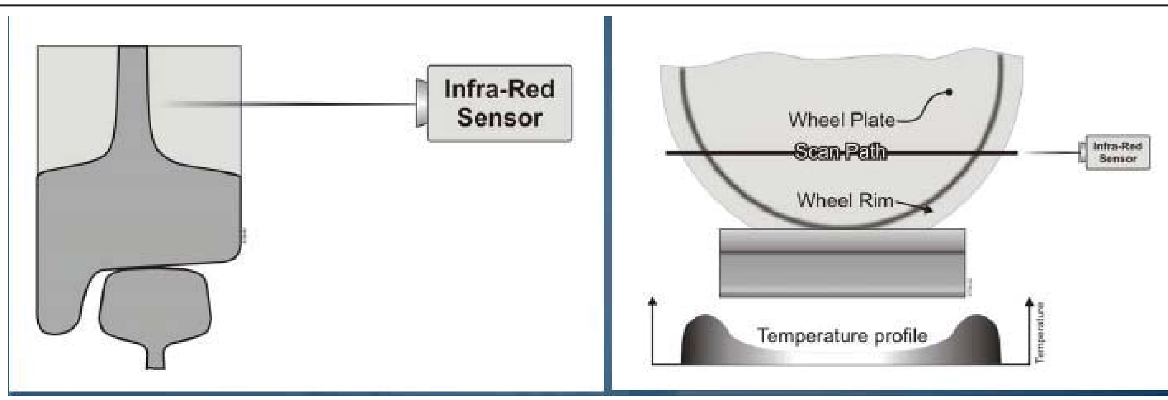


Figure 18: A Typical Arrangement of Infra-red Sensor for Sensing Wheel Plate Temperature

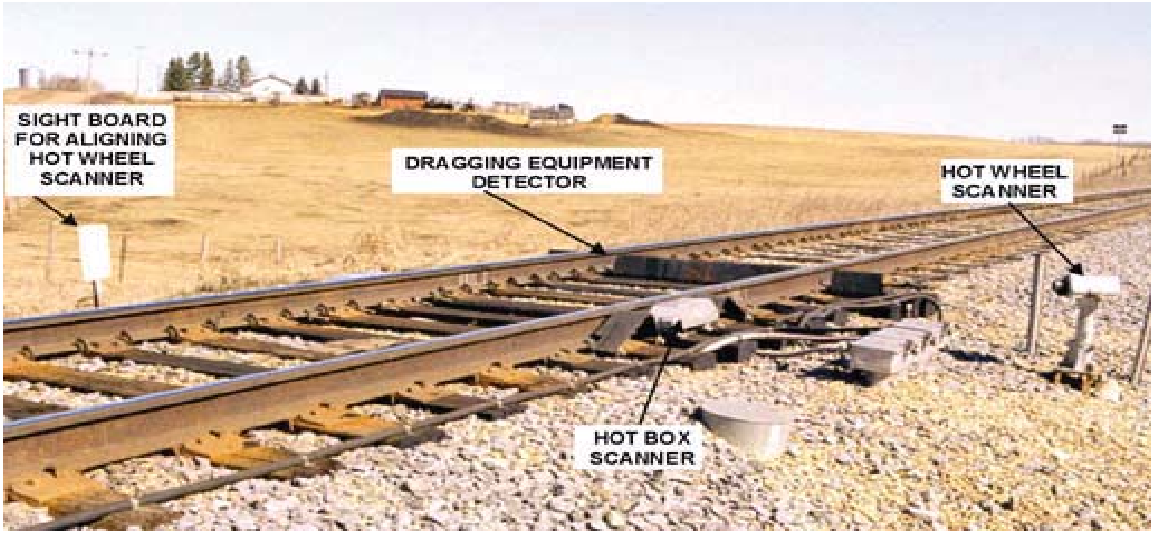


Figure 19: A Super Site on Revenue Track showing HWD, HBD and DED. The HWD has only One Scanner at an Angle to the Track with a White Reference Board on the Far Side.

- **Load Imbalance and Overload Detector (LIOD)**

These detectors are used to reduce derailment conditions and infrastructure damage by measuring vertical loads on all wheels of a car at track speeds; and consequently from these measurements detecting and alarming for overloaded rail cars or imbalanced rail cars, **Figure 20**. Since only vertical wheel loads are of essence for these detectors, **Figure 21**, they lend themselves well as add-on capabilities to the Wheel Impact Load Detectors. However, stand-alone wayside installations of these detectors may sometimes be required. Using statistical analysis of multiple vertical load measurements recorded by the detector, an estimate of the static weight of a rail car is derived to determine if the rail car is overloaded or imbalanced beyond safe operating limits.

These detectors may also provide the weigh-in-motion capability at track speed so that the need to take individual rail cars out of service for weighing is reduced. The corresponding weigh- in-motion measurements may however be affected by defective wheels, and sometimes by hunting trucks or other degraded conditions that reveal themselves in the process. As such the weighing accuracy of these detectors, as compared to the low speed or revenue-scale weigh bridges, is debatable. Their use as alternative weigh-in-motion systems is the prerogative of the railroads, their customers and the AAR.

Figure 20: A Case of Imbalance Loading of car

Figure: 21: Shown LIOD consists of an Angle Iron bolted to Rail at every Tie Location and also anchored with Rail to Ties with Elastic Clips. The Angle Iron is instrumented on Crib Locations to measure Wheel Loads. As shown, the LIOD can be detached and anchored as needed.

•

Wear of the worn wheels on an axle will always be non-symmetrical. Maintenance of trucks then requires that this non-symmetry in wear of profiles of wheel-pairs on axles of the truck be reduced to a minimum. The TBOGI, by monitoring bogie performance on straight track, provides means to access the asymmetric wheel-pair wear of an axle in terms of racking position (TP), inter-axle misalignment (IAM), tracking error (TE), truck rotation and truck shift, **Figure 22**. The TBOGI is a laser-based inspection system manufactured by WID Inc. that scans trains passing at track speed to determine by optical means the geometric faults in the alignment and tracking of bogie wheel sets on straight (tangent) track.

The TBOGI operates on the tangent track eliminating the need for a special track layout. Non-contact laser sensors are installed at a safe distance, **Figure 23**, from passing trains in order not to interfere with any track maintenance work. The measurement method embodied in TBOGI provides a wide dynamic range and yields consistent results. Wide dynamic range allows TBOGI to identify very subtle bogie performance deficiencies while also capturing gross defects. The consistency of data provided by TBOGIE allows users to trend the health of rolling stock, thereby enabling the scheduling of maintenance interventions to correct impending defects before an exception is raised or other damage is caused.

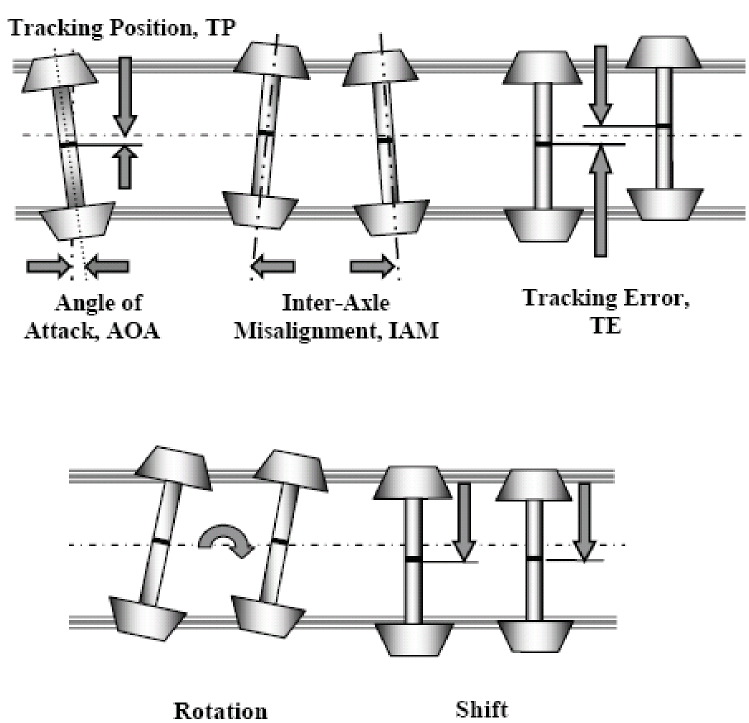


Figure 22: Definitions of Possible Displacements and Rotations in a Moving truck

Figure 23: Typical TBOGI Deployments in Freight Revenue and High Speed Amtrak Services

The features of TBOGI include

- Identifies skewed and "warped" trucks.
- Identifies misaligned trucks.
- Identifies trucks with incorrect wheel set tracking.
- Identifies trucks that wear their wheels asymmetrically ("diagonal wheel wear") even before severe wear sets in.
- Identifies trucks displaying lateral instability "truck hunting."
- Non-contact sensors installed at a safe distance from passing trains do not interfere with track maintenance work.
- Installed on tangent track, no need for special track layout.
- Measurements are insensitive to change in weather and rail lubrication conditions.
- Measure at train speed up to 250 km/h.
- Laser based sensor provides high accuracy wheel set angle of attack and tracking position information.

Acting on data produced by the TBOGI can enhance safety, reduce wheel set replacement, prolong truck component life, reduce rail wear, reduce fuel consumption, and optimize maintenance resources.

Preliminary Guidance for Interpreting Wayside Detector Data in Derailment Cause Finding / Prevention Related to Car/Equipment Only

The distress to car/equipment arising from operations involving imbalanced loading, overloading, misaligned trucks, increased grade, warped trucks, hollow wheels, out-of-round and flat-spot impacts, curved track, stuck brakes, impacts at bridge approaches, diamonds, switches, and rail joints can be monitored by wayside detection technology according to the three following strategies:

1) Wayside condition detections
    a. Cracked Axle Detector (CAD)
    b. Cracked Wheel Detector (CWD)
    c. Thermal Scan (TS)
    d. Acoustic Bearing Detector (ABD)
    e. Low Air-hose Detector (LAD)
    f. Dragging Equipment Detector (DED)
2) Wayside performance detections
    a. Truck Hunting Detector (THD)
    b. Truck Performance Detector (TPD)
    c. Wheel Impact Load Detector (WILD)
    d. Overload/Imbalance Load Detector (OILD)
    e. Warm Bearing Trending (WBT)
    f. Wheel Temperature Trending (WTT)
3) Wayside machine vision technologies
    a. Wheel Profile Module (WPM)
    b. Brake Shoe Module (BSM)
    c. Automated safety appliance inspection system (ASAIS)
    d. Automated inspection of system components (AISC)

FRA has no regulations pertaining to the data collected by wayside detectors at present. As such, all that FRA can do is to use this data, along with the railroads, in finding the causes of distress to equipment and infrastructure. To aid in this effort AAR's Field manual provides guidelines on detector calibrations and thresholds on collected data. Some of these thresholds, e.g. for WILD and THD, are also mentioned in prior detector descriptions. As an example, the AAR condemnable alert (WILD - 90 kips to less than 140 kips for single wheel) represents the regular Field Manual Rule 41 condemnable level at any time. The final alert level (WILD – 140 kips and greater for single wheel) represents a wheel having an impact force on the rail so great that it places undue stress on both the wheel and the rail.

Hunting usually occurs on empty cars at speeds greater than 50 mph. Truck hunting detector limits are given in Interchange Rule 46. The responsible party is notified through the EHMS system when a car has a truck with a single THD detector reading (Salient Systems force-based Truck Hunting Index (HI)) greater than or equal to 0.20. This is considered the Window of Opportunity when car is in home shop. However, condemnable at any time using THD detector data is defined when either 1) a single HI absolute value reads above 0.65 or 2) two HI absolute values read above 0.50 in a twelve month time period. Rule 46 requires that home shop disposition be requested from the car owner when a truck exceeds condemning limits detected by a THD wayside detector. Consequent corrective steps require that a) the affected trucks be qualified and/or repaired to AAR Specification M-214, b) condemnable friction wedges be replaced, c) if equipped with constant contact side bearings, resilient or spring elements be replaced, d) roller or block type side bearings be replaced with AAR M-948 approved long travel steel capped constant contact side bearings, and d) side bearing adjustment or component replacement be made per Rule 62. New sections were added to Field Manual Rule 46 addressing truck inspection and repair, and especially side bearing adjustment and repair Rule 62.

AAR Field manual Appendix F addresses WILD and THD detector calibration, validation and data requirements. The truck performance detector (TPD) alert criteria are given in Field Manual Rule 46.

Rules related to the acoustic roller bearing defect detectors (ABD) were added to Field Manual Rule 36. Appendix G covers initial and continuous ABD wayside detector site validation. Field Manual rule states that an ABD wayside detector Level 1 alarm represents a specific minimum amount of bearing damage corresponding to at least one of the following:

- Two square inches or more of spalled area on any one cup or cone running surface,
- One square inch of spalled area on any one cup or cone running surface and ½ square inch or more of spalled area on any one other cup or cone running surface,
- Any orange peel surface (resembling the look and texture of an orange),
- Any roller spall or seam,
- Any loose component indication
    - Cone race backface wear greater than 0.010 inch
    - Indication of spun cone on the corresponding axle journal
    - Oversize cone bore from dynamic growth and evidence of turning on axle journal,
- Two square inches or more of heavy water etched area, with indented surface(s), on cup or cone running surfaces.

If an ABD wayside detector shows a Level 1 alarm on a bearing, the car can be sent to a repair track to perform a hand roll inspection for removal or further inspection. As a rule of thumb, the reasons of hot bearings attributable to various failure progression modes, in descending order of magnitude or significance, are:

- Water etch
- Loose
- Fatigue spalling
- Bearing destroyed
- Wheel defect
- Mechanical
- Adapter
- Lubrication
- Displaced seal
- Application
- Truck related

- Manufacturing defect.

Of these above modes, spalling and water etch are detected easily by acoustics. ABD wayside detectors are an evolving technology such that with additional development, some percentage of the other failure modes may also be detectable acoustically.