TECHNOLOGY DIGEST
TD-16-058
©DECEMBER 2016
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Testing of Hot Bearing Detector 9-inch Scan Distance

Jim Cline and Tony Sultana

Summary

In 2015, the Transportation Technology Center, Inc. (TTCI) evaluated differences in revenue service between the traditional 7.25-inch and testing 9-inch bearing scan distances for hot bearing detectors (HBD). Based on the results, TTCI does not recommend any change from 7.25-inch to 9-inch scan distances at this time. The 9-inch scan distance, tested at the Transportation Technology Center (TTC) in 2013 and 2014, was achieved using the same HBD as the 7.25-inch and moving the scan position towards the center of the bearing.[1]

TTCI examined the effect on the number of high temperature bearings and the normalization of train K-values with the following results;

- Comparisons between the 7.25- and 9-inch scan distances show the number of extreme outliers (170+ °F bearing readings) is much greater for 7.25- than 9-inch scan distances.
  - There is also little overlap of the bearings with high temperatures, indicating the readings may be from different locations on the bearings or from the effect of blockage.
  - Future research will delve into this deeper; blockage of the beam at the 9-inch scan distance may be a direct cause for the reduced high temperature readings.
- The use of train K-values for the 9-inch scan distance is appropriate and consistent with the frequency rates of the 7.25-inch scan distances.
  - When examined by car type, the range and distributions of traditional 7.25- and 9-inch scan distances are similar, with more outliers for the 7.25-inch scan distance.
  - Stack and vehicular flat cars for wheel sizes of 28 and 33 inches provide results that are similar between the 7.25- and 9-inch scan distances.

Next steps in 2016 include determining the false positive and negative rates of the 9-inch compared to the 7.25-inch scan distances, as follows:

- Analyze bearings at the same site and load condition in the leading and trailing positions on the truck for differences in temperatures measured.
- Build 3D models of several trucks with HBD beams to measure the effect of blockage by side frames, frame keys, and frame bracing.
- Compare the temperatures from 7.25- and 9-inch scan distances with new technology multiple-scan HBD (one railroad provided).

Please contact **Tony Sultana (719) 225-9069** with questions or concerns regarding this *Technology Digest.* E-mail: tony_sultana@aar.com.
©2016 Transportation Technology Center, Inc. Unauthorized duplication or distribution prohibited.

INTRODUCTION

Using recent evaluation of different scan distances for HBD technologies, TTCI does not recommend changing from 7.25-inch to 9-inch scan distance at this time.

In 2013 and 2014, (Phase I and II) testing was conducted at TTC on the Railroad Test Track (RTT) using detectors provided by vendors or railroads to study various hot bearing detector (HBD) technologies to assess railcar bearing health. A total of 16 configurations of HBDs were evaluated. The current HBD technology was tested with different scan distances towards the center of the bearing. One test also changed the scan angle to measure the bearing when it is directly overhead of the detector. In addition to current HBD technology, several vendors provided multiple-scan technologies that increased the coverage of the bearing.[1]

The common freight bearing designs are Class E, F, G, and K with bearing lengths of 9 to 12 inches. These each have cup (outer race) widths ranging from 6.3 to 7.3 inches and are located on axle journals with the inboard edges within a half inch of being the same distance laterally out from the rail, see Figure 1.

Traditional HBDs scan a single small area by viewing 45 degrees upward from horizontal as the bearing moves past. Old technology restrictions precluded scan of any area with partial side frame obstruction, so this scan has been laterally located just off the edge of the cup, usually inboard at 7.25 inches from rail gage point, as seen in Figure 1. With normal lateral movement of the wheelset, this scan may view the backing ring on one pass, the cup edge on another, and the seal on most passes.

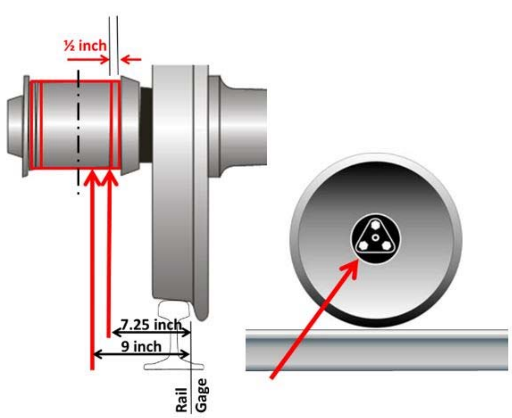

Figure 1. Scan Position of Tested HBDs

In Phases I and II, TTCI evaluated and ranked many options. A relative performance scale was used from the traditional 45-degree single scan HBD as rank 5, to the multiple-scan vertical looking HBD with best performance as rank 1.

Seven groups are shown in Table 1, similar technologies are grouped and sorted by the nominal ranking that indicate the effectiveness with different scan distances, scan angles, or multiple-scan technologies. The 7.25-inch (inboard of bearing race) and 14.00-inch (outboard of bearing race) scan distances are the predominant technologies currently used in North America.

Table 1. Rank Ordered (lower better) Effectiveness

Technology	Distance from Rail Gage Point (inch)	Nominal Ranking
Multiple scan Vertical	Various	2.1
Single scan Vertical	9.50	2.8
Single scan 45 degrees	9.00	4.0
Single scan 45 degrees	8.25 - 8.50	4.1
Single scan 45 degrees	9.50 - 11.25	4.5
Single scan 45 degrees	14.00 (current)	5.0
Single scan 45 degrees	7.25 (current)	5.0

The ranking identifies categorical improvements (lower ranking is better) in measurement performance of the technologies. For example, a rank ordering of 4.0 is categorically better than a 5.0 ranking, but cannot be translated as a specific percentage of improvement.

Railroads selected 9-inch for collocated testing since the 9-inch scan distance indicates a rank ordered improvement over current 7.25- or 14-inch scan distances, and an identical detector of those in use can be adjusted to the 9-inch scan distance. A total of 11 sites of collocated 7.25- and 9-inch detectors were provided in revenue service by two railroads.

TESTING

HBD data is used two-fold with temperature thresholds to remove bearings from service and as k-value thresholds. K-values provide a normalized value of bearing readings to identify elevated bearings relative to the trains' operations.

For instance, a slow train in the winter wind may have a defective bearing operating at 120 °F which is a typical temperature for a high speed train on a summer day. By adjusting for the nominal temperature of bearings on this side of this train pass, the significance of the 120 °F reading becomes evident. As a refinement to this approach, the scatter or variation of temperatures is taken into account as well. The calculation of the range of the central 50 percent of the data is used in the unit of measure as seen in Figure 2.

$$\boldsymbol{K}\ value_{train} = \frac{(bearing\ temp - 3rd\ quartile)}{(3rd\ quartile - 1st\ quartile)}$$

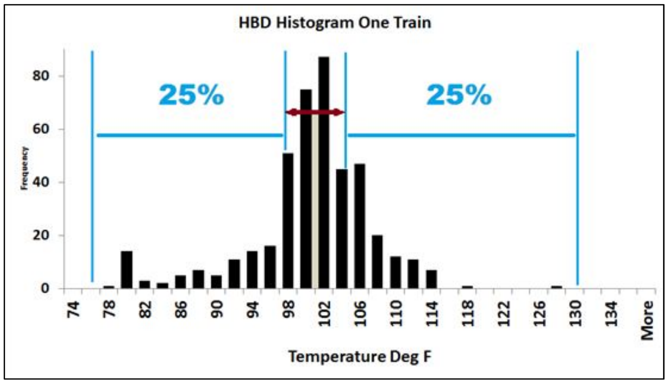

Figure 2. Example Temperature Distribution and Quartiles

Having already seen the effectiveness of the various technologies in Phases I and II, the Phase III testing is being conducted in revenue service to evaluate HBD technologies with larger traffic variations. The hottest bearings are of greatest interest and rare, thus requiring time and/or multiple sites to capture these rare cases. The primary objectives are to identify any risks in changing to a new approach, such as if the new method or device has difficulty evaluating some combination of car, truck, wheel size, and bearing. Such instances could miss alerts or create false alerts that would be identified with the current 7.25-inch scan distance.

The 9-inch scan is far enough out on the bearing to ensure each is scanned on the cup regardless of a change of lateral position by the wheelset. A test site consists of two adjacent traditional HBD sensors positioned to view each passing bearing simultaneously, as Figure 3 shows.

Any differences between 7.25- and 9-inch readings will be of unknown root cause; either a third high precision device is needed or bearing teardown inspections are required on a large number of bearings. A high precision (highly accurate and repeatable) device was selected for readings to interpret the 7.25- versus 9-inch discrepancies. TTCI installed an infrared camera for a limited time period in summer weather in this critical role.

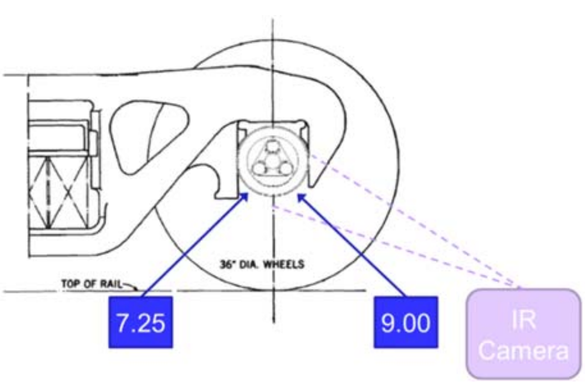

Figure 3. Collocated Installation of Detectors

ANALYSIS

Analysis of trends for these test sites has included general distribution of readings for 7.25- versus 9-inch data, outlier and extreme outlier comparison, train K-value effectiveness, and consistency of measures by bearing class, wheel size, and car type.

The *AAR Field Manual for Interchange Rules* and the *AAR Manual of Standards and Recommended Practices* prescribe the following as removal criteria for bearings in interchange service:[2,3]

- 200+ °F absolute temperature
- 170+ °F above ambient temperature with manual confirmation
- 95+ °F hotter than mate bearing on same axle with manual confirmation
- Train k-value in various circumstances

Analysis for differences in the populations of bearings in excess of 170 °F for 7.25- and 9-inch use 30.4 million bearing passes between October 2014 and November 2015, and 149 bearing passes are found to have one or both detectors with readings of 170+ °F. There are two important characteristics of these high readings:

- There is little overlap for 7.25- and 9-inch scan distances
- The 9-inch has about 1/12th the number of 170+ °F instances.

The large differences in high temperature readings (shown in Figure 4) require further work to determine if the high readings for the 7.25-inch scan distance are false alarms or missed high temperature bearings at the 9-inch scan distance. This additional work is continuing in 2016.

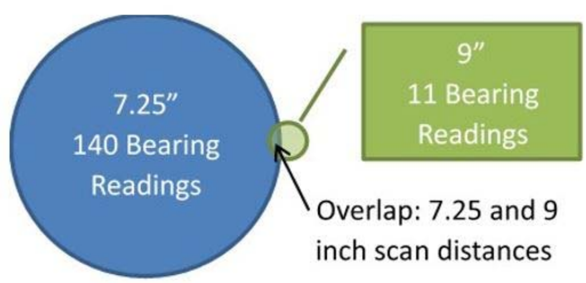

Figure 4. Diagram of the Number of 170+ °F Bearings

Analysis has been completed for the appropriateness of train k-values for 9-inch, which includes 23,924 train passes from multiple sites (see Figure 5). Overall, there is no practical difference in the train k-values between the 7.25- and 9-inch scan distances. There are some differences by train, which is expected because of the temperatures measured by both scan distances.

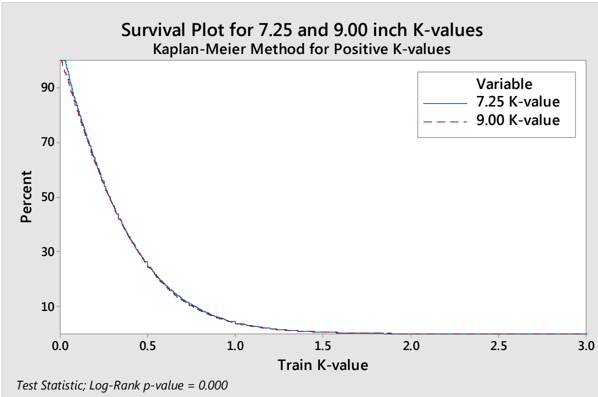

Figure 5. Comparison of K-value Frequency Distributions

Figure 6 shows the 7.25-inch scan distance has more high k-values than the 9-inch system for certain car types: covered hoppers (C), rotary gondolas (J), low profile intermodal (Q) and stack cars (S).

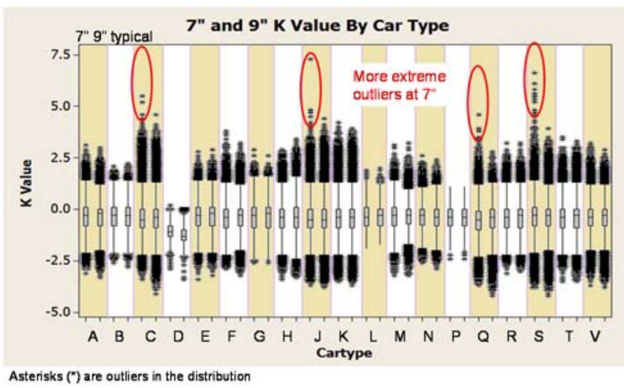

Figure 6. K-value Differences by Car Type & Scan Distance

K-values were also reviewed by wheel type. Table 2 shows a comparison of 28- and 33-inch wheels (E class bearings) that are used on autoracks (28- or 33-inch) and the outer trucks of stack cars (33-inch only).

Table 2. Positive K-value Proportions

Car/Wheel Type	Proportion of 7.25-inch scan Population	Proportion of 9-inch scan Population
S33	34%	31%
V28	45%	45%
V33	25%	22%

Positive k-values represent the upper 25 percent of the temperature data by train. When the percent is significantly higher than 25 percent, it means that more of that type of bearing/car type combination have hotter bearings than the general population. No practical differences were found between 7.25- and 9-inch scan distances when evaluating the percent of positive K-values. Results are similar for 36- and 38-inch wheel data sets overall.

CONCLUSION

Based on the test results, there is no recommendation for changing from 7.25-inch to 9-inch scan distances at this time. The number of extreme outliers (170+ °F bearing readings) is much greater for 7.25- than 9-inch scan distances. There is also little overlap of these readings, indicating the readings may be from different parts of the bearings or due to blockage of the sensor. Future research will delve into this deeper; blockage of the beam at the 9-inch scan distance may be a direct cause for the reduced high temperature readings.

The use of train k-values for the 9-inch scan distance are appropriate and consistent with the frequency of 7.25-inch scanned bearings. The range and distributions of traditional 7.25- and 9-inch scan temperature data are similar with more outliers for the 7.25-inch scan distance when examined by car type. Stack and autorack cars for wheel sizes of 28 and 33 inches provide similar readings between the 7.25- and 9-inch scan distances.

NEXT STEPS

One railroad is installing a high precision device (multiple-scan vertical looking HBD) at a test site to assist with the research. The data from the collocated multiple-scan high precision HBD technology will be used to determine false positive and false negative rates of the 9-inch compared to the 7.25-inch scan distances.

3D models are being designed of several trucks to examine blockage of the detectors by the side frame, frame keys, and frame bracing mounts.

Bearings will be analyzed at the same site and load condition in the leading and trailing positions on the truck for differences in temperatures measured.

ACKNOWLEDGEMENT

TTCI thanks CSX Transportation and Union Pacific Railroad for their support of this Strategic Research Initiative.

REFERENCES

1. Cline, Jim, Arian Bonetto, and Tony Sultana. "Evaluation of Hot Bearing Detector Technology Used to Identify Bearing Temperatures." *Technology Digest* TD-14-017. AAR/TTCI, Pueblo, CO. Rev. Aug. 2014.
2. Association of American Railroads. *AAR Manual of Standards and Recommended Practices.* Section F "Sensors" Standard S-6001 Bearing Temperature Performance. 2008.
3. Association of American Railroads. *2016 Field Manual of the AAR Interchange Rules.* Rule 36.A.15-17 Roller Bearings. WM50, WM51, WM52.

Visit our website at http://www.ttci.aar.com

Disclaimer: Preliminary results in this document are disseminated by the AAR/TTCI for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR/TTCI makes no representations or warranties, either expressed or implied, with respect to this document or its contents. The AAR/TTCI assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.