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# An Analysis of Obstruction of the Scan Area of Hot Bearing Detectors with 3-D Modeling

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## Summary

In 2016, the Transportation Technology Center, Inc. (TTCI) modeled the effects of obstruction of the hot bearing detector (HBD) device, between the traditional 7 ¼-inch and the 9-inch bearing scan distance. From the model, when an HBD scans from a 9-inch distance there is a potential for the measurement to be affected by a frame brace mount, frame key, or the side frame itself.

The 9-inch scan distance, tested at TTCI in 2013 and 2014, is achieved using the same HBD as the 7 ¼-inch and moving the scan position towards the field side of the car and closer to the center of the bearing. The 2013 and 2014 tests did not consider truck configurations with frame keys or frame bracing mounts that could produce obstruction of the sensor. The modeling focuses on potential obstruction caused by the side frame, frame keys, and frame bracing mounts on 70-, 100-, and 125-ton trucks.

Models using a three-dimensional (3-D) computer aided drawing (CAD) program show that for the 7 ¼-inch scan distance there are no obstructions when the wheelset is tracking centered on track. In the lateral position of the 9-inch scan distance there are obstructions from the frame, frame key, and frame brace mount that reduce the scan surface of the bearing. The worst obstructions for each truck weight are as follows:

- A 7 ¼-inch scan distance can nominally scan the maximum potential of the bearing surface.
- A 9-inch scan distance, with a frame brace mount, can nominally scan 8.41 inches of the maximum potential of 16.67 inches (50.4 percent) of the bearing surface on the 125-ton truck.
- A 9-inch scan distance, with a frame key, can nominally scan 9.07 inches of 14.81 inches (61.2 percent) on the 100-ton truck.
- A 9-inch scan distance, with a frame key, can nominally scan 7.34 inches of 13.41 inches (54.7 percent) on the 70-ton truck.

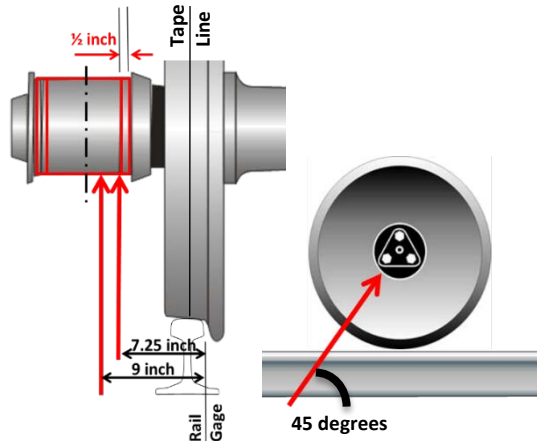
Blockage identified in this analysis could result in lower temperatures being reported for bearings.



**INTRODUCTION**

In 2013 and 2014, (Phases I and II) testing was conducted at the Transportation Technology Center (TTC) on the Railroad Test Track (RTT) using detectors provided by vendors or railroads to study the effectiveness of various hot bearing detector (HBD) technologies to assess railcar bearing health. A total of 16 configurations of HBDs were evaluated. The current HBD technology used in service was evaluated, being placed at 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 increase the coverage of the bearing.

Traditional HBDs scan a single small area by viewing 45 degrees upward from horizontal as the bearing moves past. In HBDs used in revenue service the scan has been laterally located just off the edge of the cup, usually inboard at 7¼ inches from the 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 pass, and the seal on other passes, resulting in different temperature readings.



**Figure 1. Scan Position of Tested HBDs**

In Phases I and II, TTCI evaluated and ranked all the tested options. A relative performance scale was used from the traditional 45 degree single scan as rank 5.0, to the vertical look multiple scan with the best performance as rank 1.0.

Seven groups are shown in Table 1 with similar technologies grouped and sorted by the nominal ranking that indicates the effectiveness with different scan distances, scan angles, or multiple-scan technologies. The 7¼-inch (inboard of bearing race) and 14-inch (outboard of bearing race) scan distances are the predominant technologies currently in use 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.

Several railroads selected 9-inch scan distance at 45 degrees for collocated testing since the 9-inch scan distance indicates a rank ordered improvement over current 7 ¼- or 14-inch scan distances, and an identical detector of those in use that can be adjusted to the 9-inch scan distance.

Moving the scan distance from rail to 9 inches could possibly introduce some complications for accurate measurements. Certain truck components, in particular side frames, frame keys and frame brace mounts, could potentially interfere with measurements taken at 9 inches from rail. A thorough model of the truck configuration systems could identify potential blockage problems for the 9-inch scan distance.

**MODELING AND MEASUREMENTS**

In order to determine if there is any part of the frame system that would block the view of the bearing from the sensor, the system was modeled in SOLIDWORKS®, a 3-D CAD program. The model includes a standard axle, wheel, side frame, bearing, and rail for each truck weight. The truck sizes were chosen because they are the most common in revenue service and span the size of bearings E, F, K, and G.

The sources of the measurements used for the 3-D model were taken from the *AAR Manual of Standards and Recommended Practice* for axles, side frames, and wheels,<sup>1,2,3</sup> and from manufacturer drawings and measurements for bearings and frame bracing.

From information provided by HBD suppliers, it is estimated the sensor views an oval area of the bearing about 3 inches in length and 1 inch in width.

The measurements taken from the 3-D model determine how much of the bearing surface is visible to the HBD during its pass over the sensor. There are two important distances in this analysis, the linear distance along the rail and the distance along the bearing surface. In all cases, the wheelsets are determined to be traveling central to the track, see Figure 1.

Figure 2 shows the relationships between the bearing diameter, the linear distance along the rail during a sensor scan, and the scanned distance along the bearing surface.

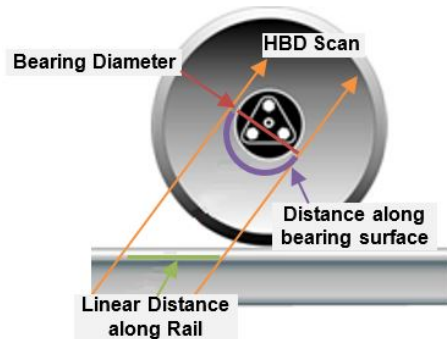


Figure 2. Relationships of Sensor Measurements

The linear distance along the rail is the measure of the distance in direction of travel the bearing is visible to the HBD sensor. Table 2 gives the diameters for each bearing type associated with the truck weights examined in the model and the distances along the rail from when the midpoint of the scan area first contacts the bearing to when the midpoint of the scan area ends contact with the bearing.

Table 2. Bearing and Scan Dimensions in inches

	70-ton truck	100-ton truck	125-ton truck
Bearing Diameters	9.01	9.85	10.53
<b>Scan Linear Distance (Along Rail)</b>			
Maximum Potential	11.69	13.00	15.07
7 ¼-inch scan distance	11.69	13.00	15.07
9-inch side frame only	5.50	7.00	8.00
9-inch w/ frame key	4.00	5.50	6.50
9-inch w/ frame brace mount	X	X	4.50

The blockage of the 9-inch scan introduced by the side frame, frame key, and frame brace mount can be seen in Figure 3, Figure 4, and Figure 5, respectively. The 9-inch scan is represented by the yellow beam. The 7¼-inch scan is represented by the purple beam. Note that these obstructions occur only in the direction indicated. If the bearing approaches the sensor from the other direction, the truck presents only a smaller side frame profile, as Figure 6 illustrates.

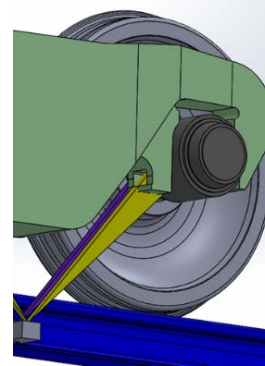


Figure 3. Side Frame Obstruction for 9-inch

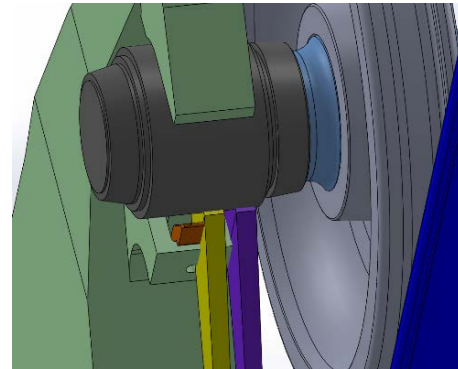


Figure 4. Frame Key Obstruction for 9-inch

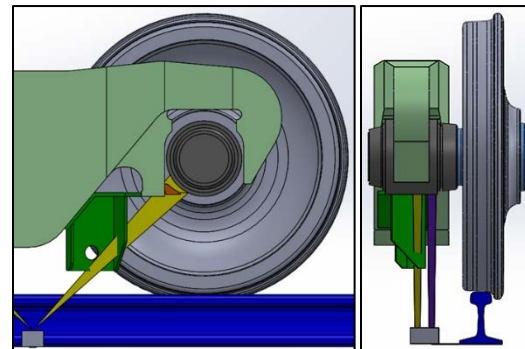


Figure 5. Frame Brace Mount Obstruction for 9-inch

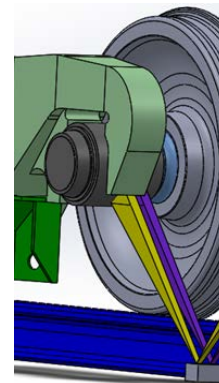


Figure 6. Opposite Approach Direction Scan

Table 3 contains the calculated scan distances along the surface of the bearings for each condition, using the Arc Length Formula.<sup>3</sup>

**Table 3. Scan Distance along Surface of Bearing in inches**

	70-ton truck (inches)	100-ton truck (inches)	125-ton truck (inches)
Maximum Potential	13.41	14.81	16.67
7 ¼-inch scan distance	13.41	14.81	16.67
9-inch side frame only	8.71	10.34	11.47
9-inch w/ frame key	7.34	9.07	10.24
9-inch w/ frame brace mount	N/A	N/A	8.41

**DISCUSSION**

Since the 9-inch setting of the HBD will scan a smaller surface of the bearing under specific circumstances, it will necessarily obtain fewer temperature samples of the bearing to obtain an accurate measurement for those circumstances.

Any system that uses an approach requiring multiple samples of the bearing to determine bearing temperature will be adversely affected by obstruction, as the sensor would be scanning lower temperature frame parts for samples instead of the bearing. From Table 2, the 9-inch setting scans only 54 percent, 61 percent, and 50 percent of the 70-, 100-, and 125-ton trucks, respectively, of the maximum potential of the bearing surface under the worst obstruction.

For other types of HBD sampling algorithms, a smaller measurement space could cause accuracy issues. For example, if the HBD uses the maximum obtained value for the measurement, a large obstruction could prevent an accurate reading. This inaccuracy is either because the hottest part of the bearing is obstructed, or the transducer does not have enough time to react to the real temperature of the bearing when it becomes visible to the sensors.

As previously stated, the wheels are modeled traveling along the tape line of the wheel. For the 7 ¼-inch scan distance, lateral movement could produce blockage for the stated obstructions or measuring more of the bearing seal in place of the bearing. For the 9-inch scan distance with lateral movement, more obstruction could be experienced than modeled.

**CONCLUSION**

Models in the 3-D CAD program show obstructions for the 9-inch scan distance from the frame, frame key, and frame brace mount that reduce the scan surface of the bearing. The worst obstructions for each truck weight are as follows:

- A 7 ¼-inch scan distance can nominally scan the maximum potential of the bearing surface.
- A 9-inch scan distance, with a frame brace mount, can nominally scan 8.41 inches of the maximum potential of 16.67 inches (50.4 percent) of the bearing surface on the 125-ton truck.
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- A 9-inch scan distance, with a frame key, can nominally scan 7.34 inches of 13.41 inches (54.7 percent) on the 70-ton truck.

Blockage identified in this analysis could result in lower temperatures being reported for bearings.

**NEXT STEPS**

One railroad is installing a high precision device (multiple-scan vertical looking HBD) at a test site as an accurate base measure of temperature to assist with the research to determine overall quality of the 9-inch compared to the 7 ¼-inch scan distances. Bearings are also being analyzed at the same site and load condition in the leading and trailing positions on the truck for differences in temperatures measured.

**ACKNOWLEDGEMENT**

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**REFERENCES**

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