UNIVERSITY TRANSPORTATION CENTER FOR RAILWAY SAFETY

The University of Texas Rio Grande Valley

AN ANALYSIS OF THE EFFICACY OF WAYSIDE HOT-BOX DETECTOR DATA

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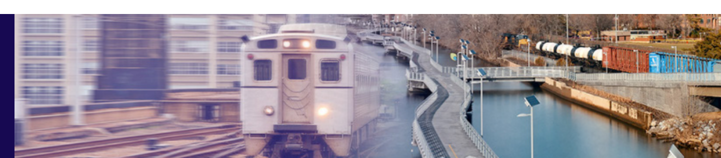
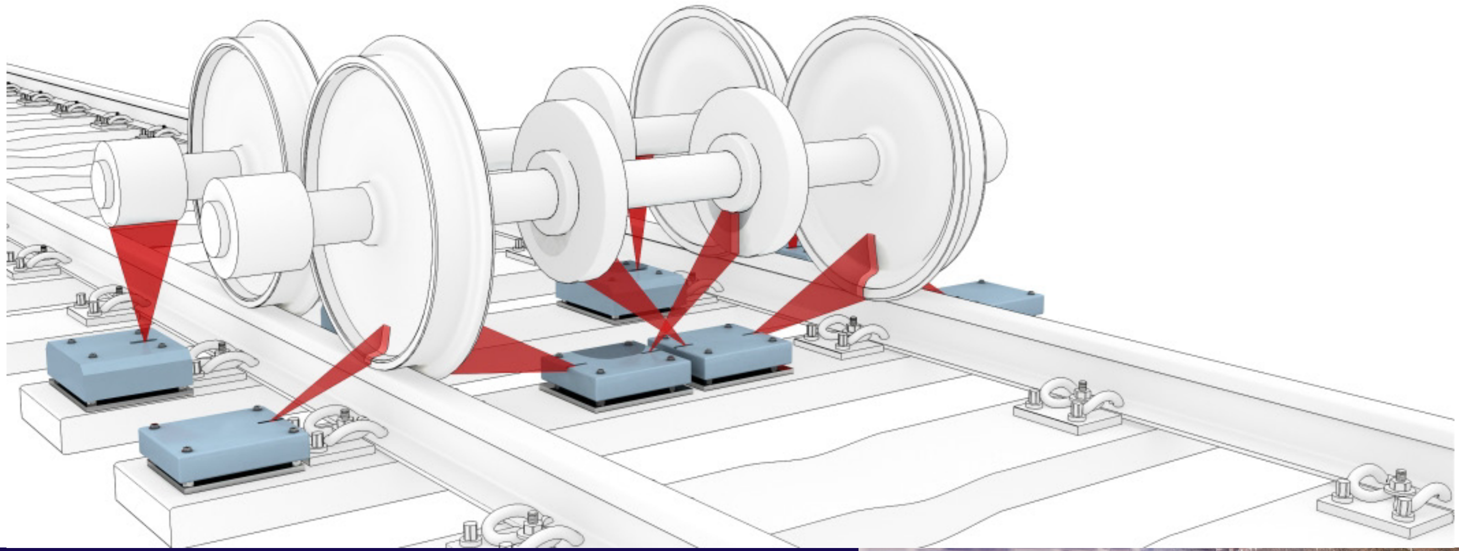


Objective

To investigate, research, and assess the use of infrared, non-contact temperature measurement technology used in wayside hot-box detection systems by comparing data acquired in the field to data obtained in a laboratory setting.

Hot-Box Detectors (HBDs)

- Hot-Box Detectors (HBDs) use infrared sensors to measure the temperature radiated from bearings, wheels, axles, and brakes.
- Over 6,000 in use in the U.S. [1]
- 119 train derailments due to overheated bearings from 2010 to 2016 in the U.S. and Canada. [2]



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Outline

- Laboratory and Field Test Setups
  - Developed Hot-Box Detector Simulation System
- Experimental Analysis
  - Experimental Parameters
- Experimental Results
  - Class F and K Bearing Operating Temperatures
  - Field Test and Laboratory Test Comparison
  - Root-Mean-Squared-Error (RMSE) and Coefficient of Determination (R^2) Comparison
- Conclusions

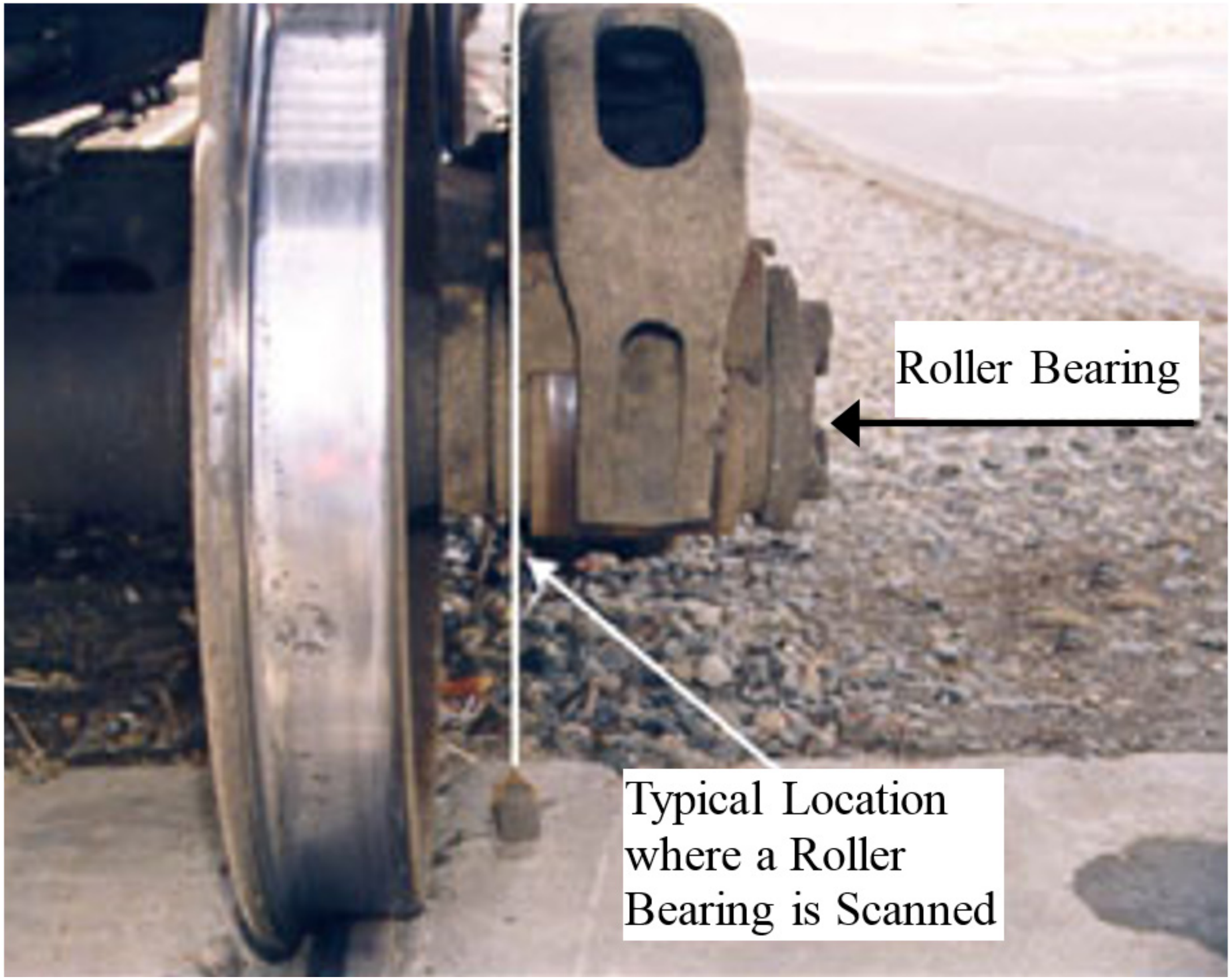

Figure 1: Typical infrared sensor scanning location for field test wayside hot-box detectors (HBDs) [4]

Field Test Setup

- Two freight cars, one unloaded and one loaded, were tested along more than 300 miles of track with 21 wayside hot-box detectors
- Of the 16 roller bearings, 12 were Class F and 4 were Class K
- 3 Class F bearings where removed from service due to a defective inner ring, a defective outer ring, and a loose cone/cage assembly
- 2 Class F bearings and 1 Class K bearing were previously removed from service and found to be “non-verified” after inspection

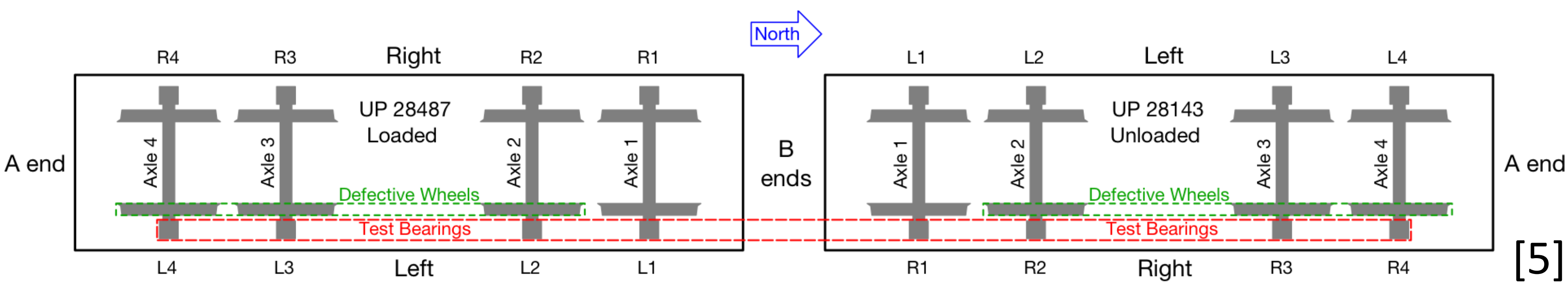

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Figure 2: Single Bearing Test Rig

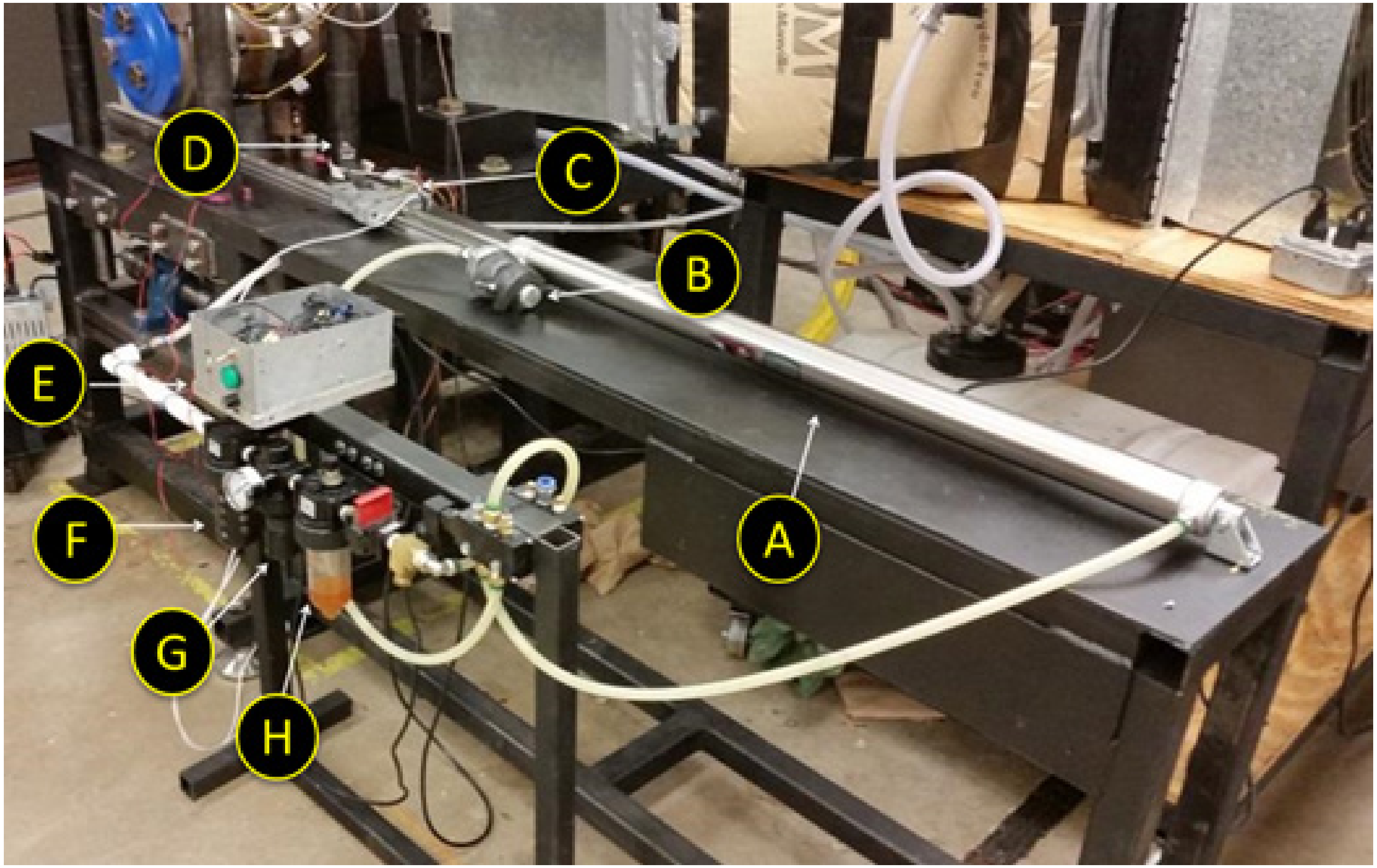


Figure 3: Hot-Box Detector Simulation System. From A through H there is the cylinder [A], the quick exhaust valve [B], the cart [C] with the sensor [D] attached, the control box [E], the filter [F] for the pneumatic system followed by the regulator [G] and the lubricator [H].

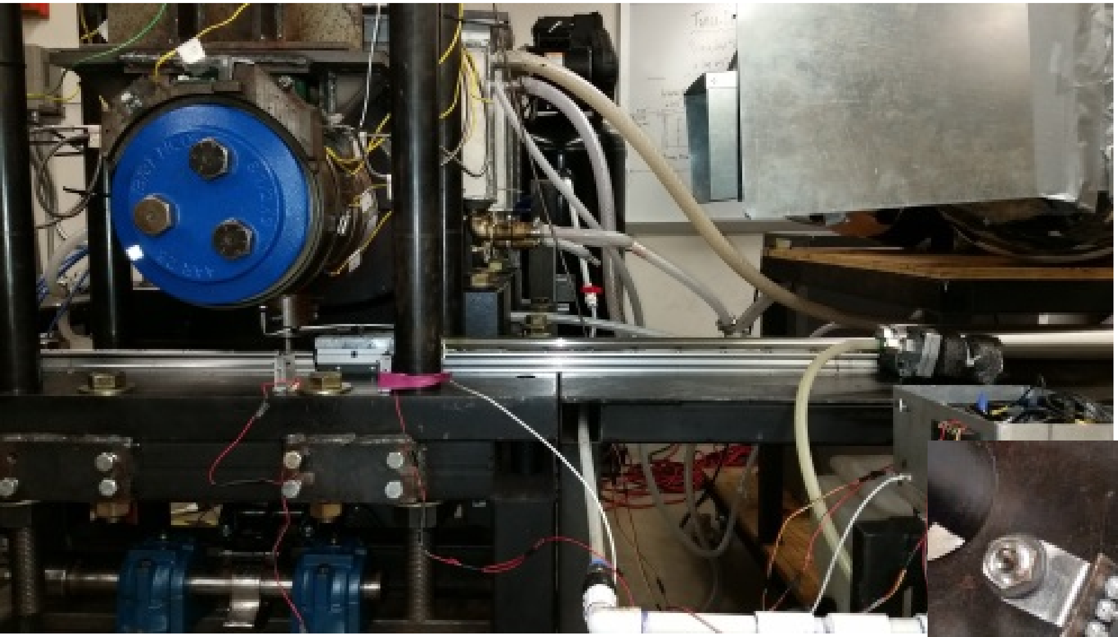
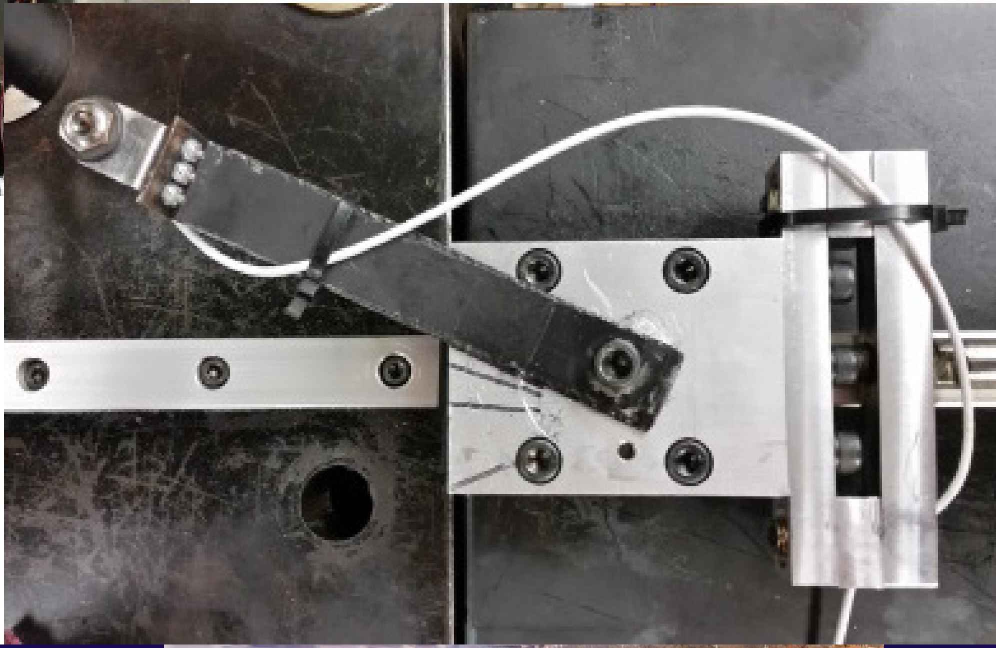


Figure 4: Side-view of the hot-box detector simulation system and the single bearing test rig.

Figure 5: Top-view of the cart that transports the IR sensor showing the markings on the cart that correspond to the four regions of interest. The bottom mark corresponds to the outboard raceway region followed by the spacer region markup, then the inboard raceway region markup. The current position of the IR sensor, shown in this picture, corresponds to the inboard seal region.



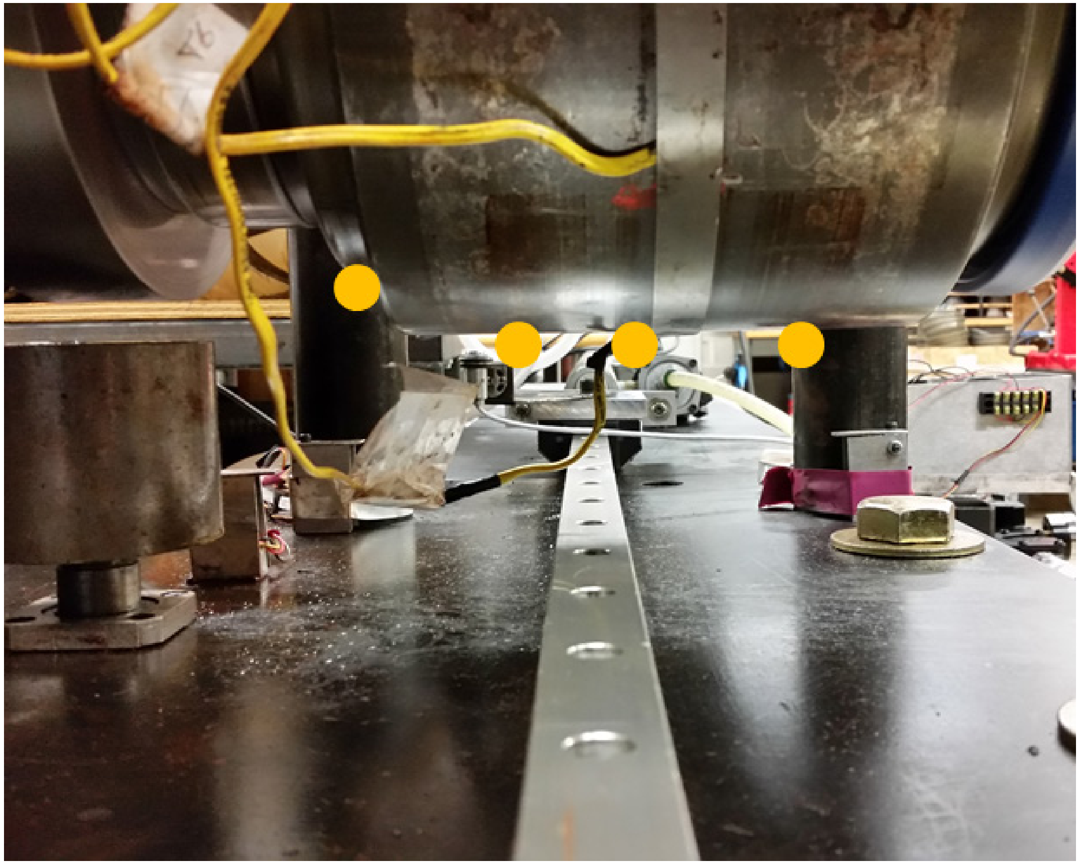


Figure 6: Infrared scanning locations from left to right: inboard seal, inboard raceway, spacer, and outboard raceway

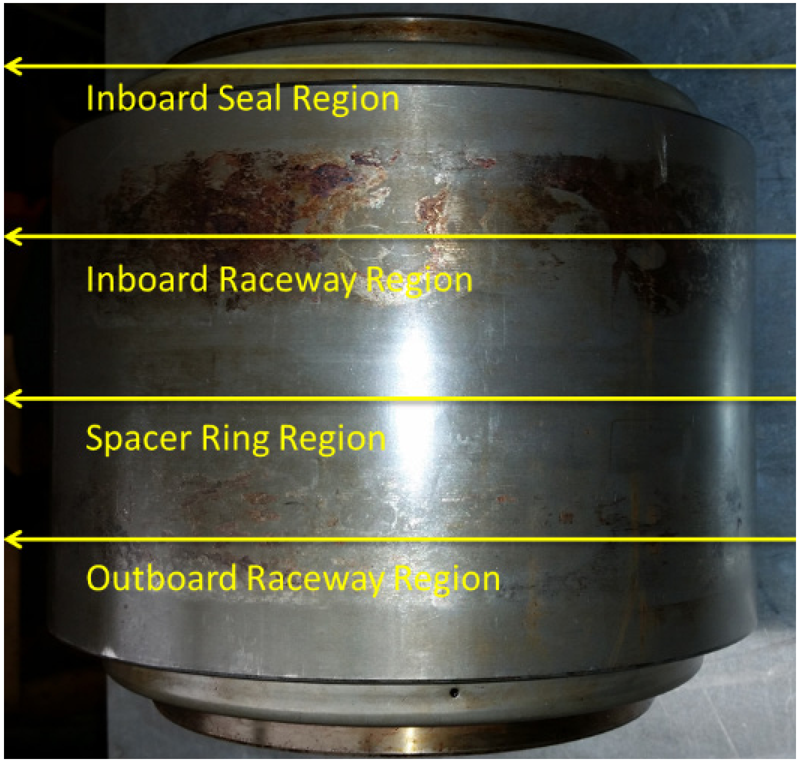


Figure 7: Infrared scanning locations on the bearing

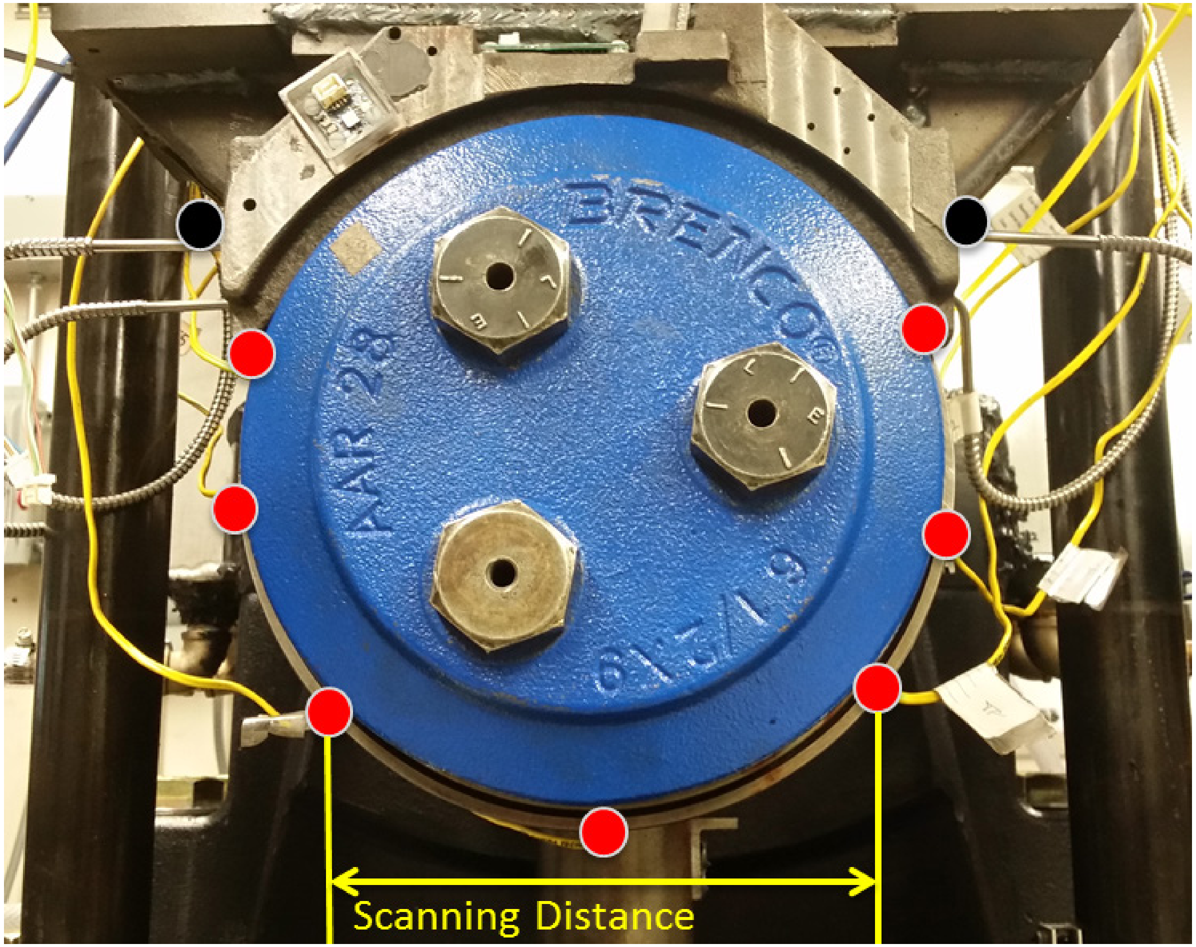


Figure 8: Bearing thermocouple locations where each red dot is a standard K-type thermocouple and the black dots represent spring-loaded bayonet-style K-type thermocouples

Experimental Parameters

Bearing Cup Positions

- Outboard (OB) Raceway
- Spacer Ring
- Inboard (IB) Raceway
- Inboard (IB) Seal

Loading Conditions

- Unloaded or Empty Car (26 kN, 5.85 kips)*
- Loaded or Full Car (153 kN, 34.4 kips)*

*Load per Bearing

Experimental Parameters

Axle Speed [rpm]	Railcar Speed [mph]	Railcar Speed [km/h]
280	30	48
327	35	56
373	40	64
420	45	72
467	50	80
498	53	85
514	55	89
560	60	97
618	66	106
699	75	121
799	85	137

Experimental Results

- Class F and K Bearing Operating Temperatures
- Field Test and Laboratory Test Comparison
- Root-Meat-Squared-Error (RMSE) and Coefficient of Determination (R^2) Comparison

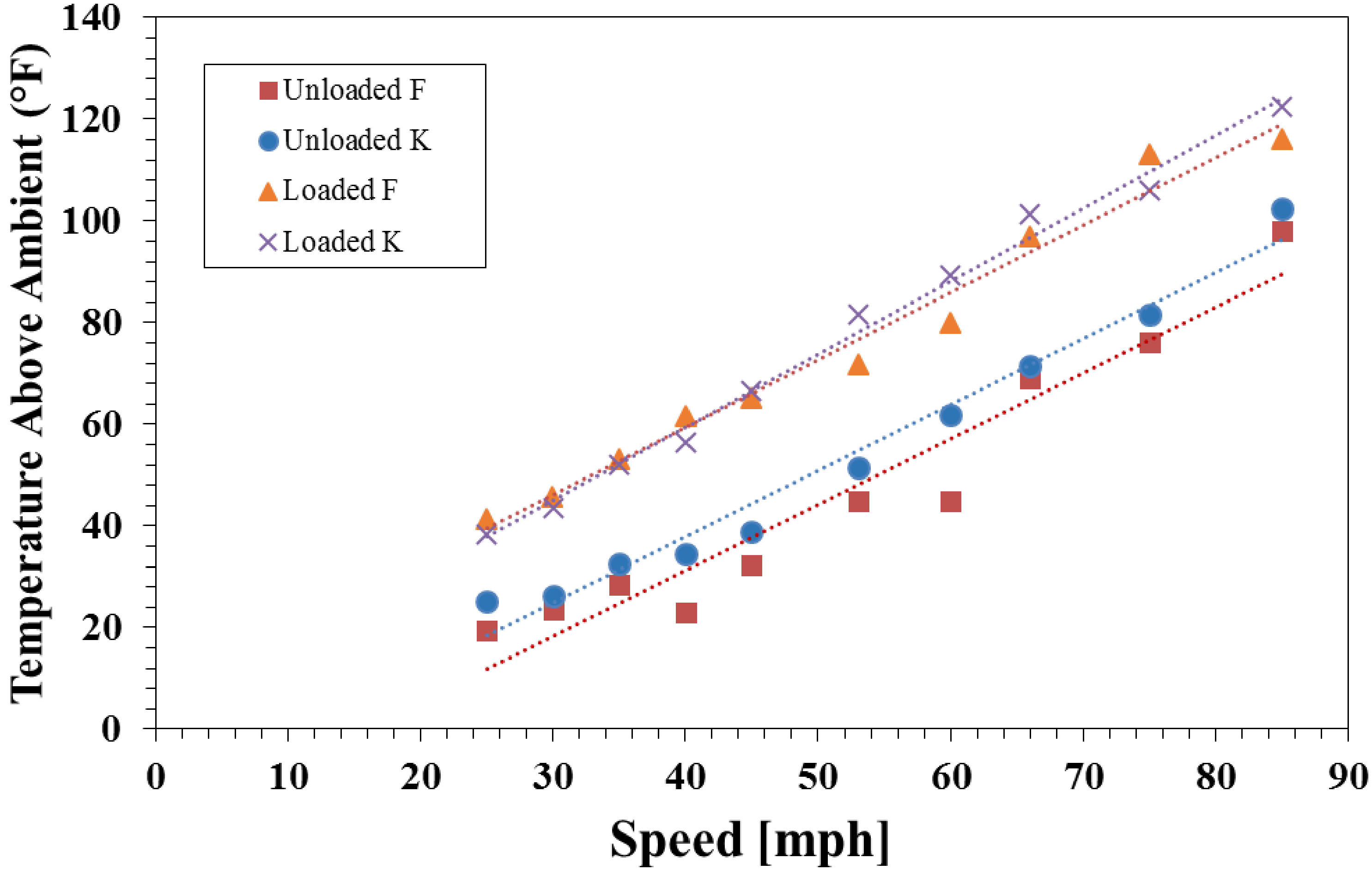


Figure 9: Class F and K bearing operating temperatures for loaded and unloaded conditions at various speeds [Ambient Temperature = 78°F (26°C)]

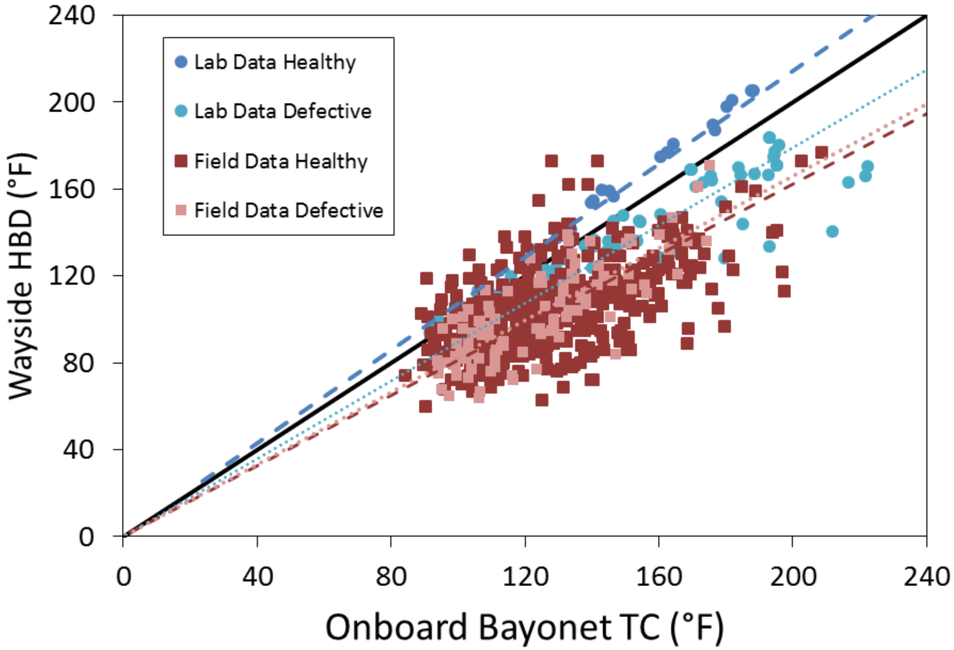


Figure 10: Wayside HBD temperature versus onboard thermocouple temperature for the laboratory bearing outboard (OB) raceway location

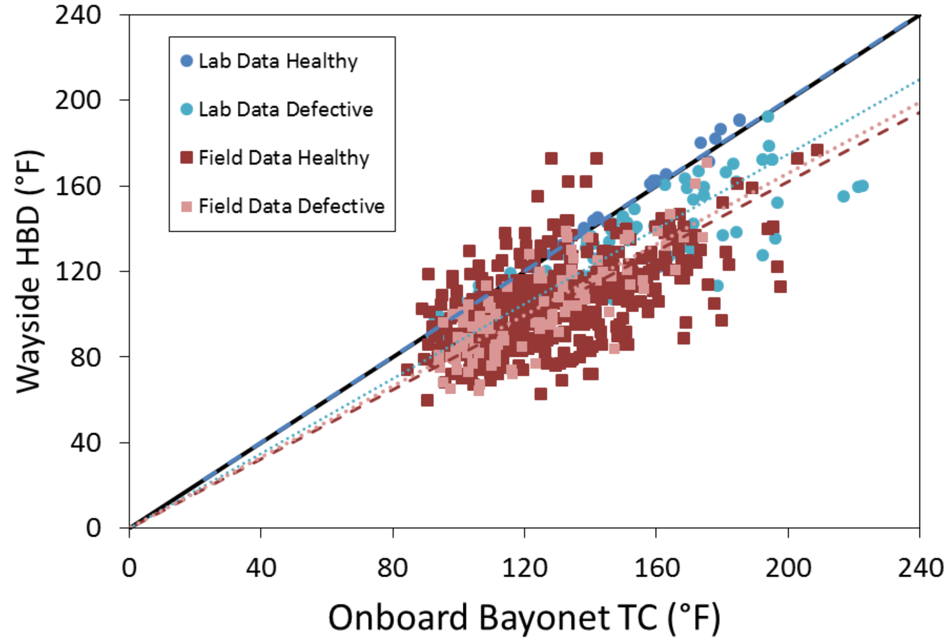


Figure 11: Wayside HBD temperature versus onboard thermocouple temperature for the laboratory bearing spacer ring location

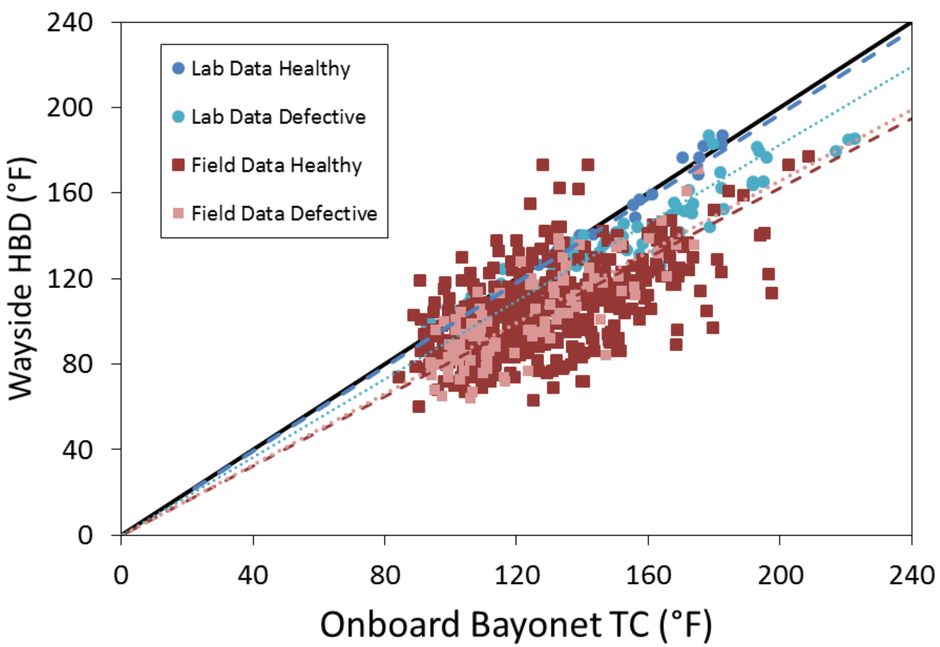


Figure 12: Wayside HBD temperature versus onboard thermocouple temperature for the laboratory bearing inboard (IB) raceway location

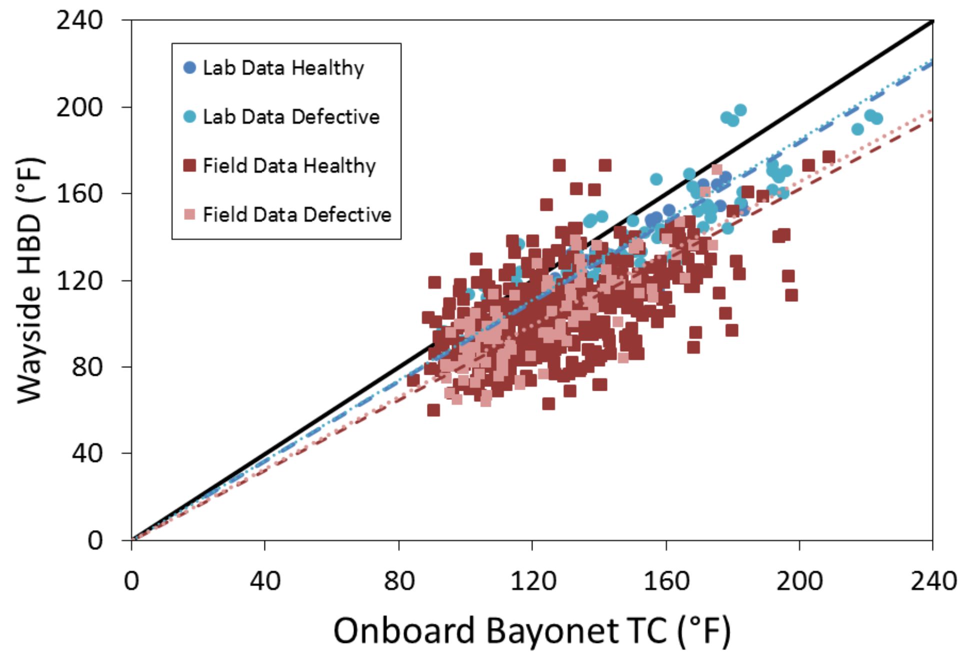


Figure 13: Wayside HBD temperature versus onboard thermocouple temperature for the laboratory bearing inboard seal location

Field Test Bearing Temperature Data Error

ΔT [°F] (IR-TC)	Class K Unloaded	Class F Unloaded	Class F Loaded	Total
	Percentage (%)			
Above 20	8	0	1	2
0 to 20	28	10	4	9
0 to -10	12	18	8	12
-10 to -20	22	29	20	24
-20 to -30	12	18	22	19
Below -30	19	26	46	35

Laboratory Bearing Temperature Data Error for Unloaded Bearings

ΔT [°F] (IR-TC)	OB Raceway	Spacer Ring	IB Raceway	IB Seal
	Percentage (%)			
Above 20	0	0	0	0
0 to 20	38	26	29	32
0 to -10	47	55	44	50
-10 to -20	9	12	21	12
-20 to -30	6	6	6	3
Below -30	0	0	0	3

Laboratory Bearing Temperature Data Error for Loaded Bearings

ΔT [°F] (IR-TC)	OB Raceway	Spacer Ring	IB Raceway	IB Seal
	Percentage (%)			
Above 20	5	0	0	0
0 to 20	19	21	8	13
0 to -10	28	19	37	23
-10 to -20	26	28	27	33
-20 to -30	9	10	17	21
Below -30	13	22	12	10

RMSE and R^2 Values for Laboratory Data

Data Description		RMSE	R^2
Class K Unloaded	OB Raceway	11.1	0.81
	Spacer	8.9	0.89
	IB Raceway	8.8	0.94
	IB Seal	10.0	0.83
Class K Loaded	OB Raceway	22.7	0.51
	Spacer	25.8	0.53
	IB Raceway	17.1	0.79
	IB Seal	18.3	0.75
All Class K	OB Raceway	19.9	0.68
	Spacer	22.1	0.67
	IB Raceway	15.1	0.87
	IB Seal	16.2	0.83

RMSE and R^2 Values for Field Data

Data Description	RMSE	R^2
Unloaded Class F	25.8	0.17
Loaded Class F	33.4	0.46
Unloaded Class K	22.9	0.13
Unloaded and Loaded Class F	30.4	0.45
Unloaded Class K and F	25.1	0.19
All Class K and F	29.6	0.39

Conclusions

- It was observed that infrared (IR) temperature data acquired in the field and laboratory generally under-predict bearing temperatures
- As expected, the data obtained in the laboratory is generally more precise and more accurate than the field acquired HBD data
- The field data also show that there is an inherent bias in the readings where the wayside HBDs tend to overestimate Class K bearing operating temperatures much more frequently than Class F bearing temperatures under similar speed and load service operation conditions.

Conclusions

- The field test HBDs over-predicted the temperature of many healthy bearings and exhibited many false trending events
- Two very important and alarming findings of this study are that:
  - The IR sensors (both in the laboratory and in field HBDs) tend to predict higher temperatures for healthy bearings than for defective bearings
  - The field test HBDs underestimated the loaded Class F bearing temperatures by more than 17°C (31°F) almost half of the time
- It was found that the inboard (IB) raceway scanning location is the most precise and accurate location to measure the temperature of the bearing using infrared-based sensors

Acknowledgements

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