

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

Locomotive Undercarriage Thermal Scanning (LUTIS)

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Key Findings:

- TTCI worked with two vendors to develop and evaluate Locomotive Undercarriage Thermal Scanning systems on the high tonnage loop at TTC.
- Both systems operated reliably in the environment at TTC.
- Both systems were able to detect a hot plate as abnormal during testing.
- Validation testing with on-board thermocouples revealed close temperature correlation with the LUTIS measurements.
- Revenue service testing of LUTIS is recommended.

Transportation Technology Center, Inc. (TTCI) is working with two independent suppliers to develop locomotive undercarriage thermal inspection systems (LUTIS) for monitoring the temperature of running locomotive components.

Modern locomotives are equipped with many on-board sensors, but certain high-load mechanical components, such as the gear train, remain unmonitored. An overheated gear box event may not be sensed by the onboard diagnostics, nor by existing wayside detector technologies. The study, performed at the request of the Association of American Railroads (AAR) Railway Technology Working Committee (RTWC), presents methods for sensing and monitoring major mechanical components such as the gear case or traction motor.

This *Technology Digest* provides results from both functional prototypes installed on the High Tonnage Loop (HTL) at the Transportation Technology Center (TTC) in Pueblo, CO. Supplier 1 produced a two-camera system with cameras placed outboard near the gage face of each rail for viewing the gear box and end components of the traction motor. Supplier 2 produced a single camera system with wide angle lens that is centered between the rails. Component views and system outputs vary between the systems. The system from Supplier 1 provides a clear view of the end components on the traction motors and is configured to distinguish abnormally elevated temperatures. The system from Supplier 2 provides a shallower view of the end components and measures component temperatures directly.

Initial results for both systems show good repeatability within the operating conditions tested. Both systems are able to distinguish abnormally hot zones. A validation test was performed where thermocouples were placed on select components of the locomotive. Correlation between the thermal image temperature measurements and thermocouple instruments was within 1°C for the system from Supplier 2.

SUPPLIERS

TTCI worked with two suppliers to develop independent systems. Both were provided with a set of requirements which included the specifications for a production-ready revenue service installation. Also, to mitigate risks, the parties

agreed to a phased approach. In the first phase, both suppliers used rented cameras to perform ranging and camera placement studies. Each supplier took a different approach toward a solution. Supplier 1 produced a two camera system with cameras located near the gage side of each rail (Figure 1). These cameras are positioned to see up between the wheels and traction motor to get the best view of the gear box and hardware that may be obscured by the traction motor from below. This configuration provides visibility of the components regardless of locomotive type or orientation.



Figure 1. Two-camera LUTIS from Supplier 1

The operation of this system from Supplier 1 is essentially to monitor temperatures in the overall field of view and alarm on abnormally elevated temperatures.

Supplier 2 opted for a single camera system centered between the rails (Figure 2). Special optics and a wide angle lens are used to view the heat signature of undercarriage components. This system is installed near the vendor's optical undercarriage imaging system, providing additional options for data viewing and component identification.



Figure 2. Single camera LUTIS from Supplier 2

REQUIREMENTS

LUTIS is a new concept suggested by the railroads for monitoring locomotive components that may not be adequately tracked by on-board sensing systems. Thermal sensors, such as bearing hot box detectors, are common on the railroads. But there is no precedent for monitoring the thermal signature of undercarriage components. While the system configurations selected by each vendor are quite different, they both were created based on the following requirements. Specifically, LUTIS will:

- Be a component health monitoring system designed to automatically monitor the thermal signatures of locomotive undercarriage components at line speed.
- Provide the capability to automatically identify components and assess component thermal signatures on railroad locomotives operated over the system.
- Conduct inspections automatically on a 24-hour per day/365-day per year basis.
- Operate reliably and accurately in the environment encountered at the wayside installation site.
- Identify component conditions that are non-compliant (out of range temperature) according to the requirements of the operating railroad.
- Collect and archive data on a per car/locomotive basis using available consist data and generate alarm reports and provide customer notification when non-compliant conditions are detected.
- Provide data export and archive capability according to individual railroad requirements. It must perform internal self-test, diagnostic and health monitoring activities to create periodic status reports, annunciate out-of-tolerance performance and generate alarm reports and customer notification when the system is out-of-service, off-line, or producing inaccurate data.

Further, LUTIS components and technologies employed must be technically mature and adaptable to the North American freight rail environment.

TESTING

Testing progressed in several steps as the systems matured. Initial testing involved establishing the range of normal operating temperatures for locomotive components. Each

vendor configured their system to monitor the FAST train during nightly operations. When a strong correlation with ambient temperature was observed, Supplier 2 elected to change thermal cameras to improve temperature resolution

In order to provide system validation data, TTCI installed thermocouples on various undercarriage components of a FAST locomotive. Locations included the traction motor housing, gear box, bearing housings, and trainline. Figure 3 shows some of these thermocouples.



Figure 3. Thermocouples were placed on select components.

The thermocouples were attached to an unmanned data acquisition system (UDAC) that monitors, records, and transmits data automatically. Figure 4 shows the UDAC system. TTCI configured this device to average data from each thermocouple as the locomotive passed by the detectors. This provided time-synchronized temperature results as the train was passing each system. The vendors could use this data to validate temperature readings.

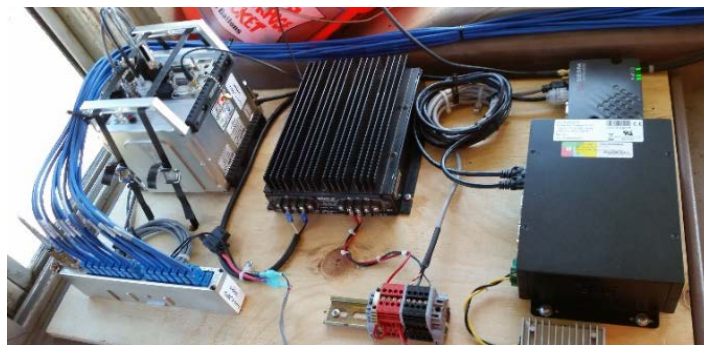
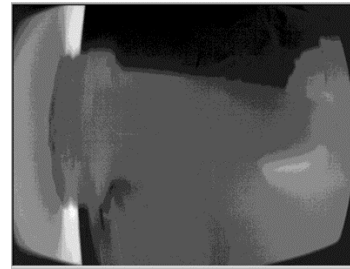


Figure 4. UDAC data acquisition system

SUPPLIER 1 RESULTS

Supplier 1 monitors the distribution of component temperatures within the view. Figure 5 is an example of the drive end of the traction motor and the temperature distribution over the components within the image.



Object 0 Data:			
MIN	:	59.000000	
MAX	:	68.000000	
MEAN	:	61.904945	
STDDEV	:	1.545615	
MEDIAN	:	62.000000	

Figure 5. Grayscale thermal image of the traction motor and corresponding temperature statistics

The overall temperature range on these components for this run is about 9°F and is normally distributed. The temperature values vary continually with ambient, but the range of variations does not. As such, alerts are suggested for components with a large delta above ambient. To validate this approach, a hot plate was attached to the underside of a test train. Figure 6 shows a table of temperature results from this test run at a starting ambient temperature of about 45°F (7°C).

The components warmed up consistently over several passes of the LUTIS as ambient and solar load increased and as the locomotive was worked. The sump drainpipe and the traction motor showed highest maximum temperature of the normal components monitored. When the hot plate was turned on, it dominated the thermal signature and was immediately identified. The reading corresponding to the sump drainpipe was investigated further. The elevated reading was determined to be from a difference in emissivity due to a drop of oil on the pipe.

Feature	Max °C	Min °C	Med °C
Hot plate	> 255	10	42
Sump drain pipe	103	7	42
Wheels	51	7	37
Coupling	42	7	34
Traction Motor	62	10	45

Figure 6. Temperature statistics for a test run with hot plate

Supplier 1 is developing algorithms that will alert when a monitored component exceeds a delta from ambient.

SUPPLIER 2 RESULTS

Supplier 2 uses a single camera centered between the rails. It has a wide angle lens to capture the entire width of the locomotive underside in a single view. The camera is a line-image camera that scans temperatures on narrow slices. These

slices are combined using input from a high accuracy speed sensor to create a full mapping of the temperature distribution. A template is applied to the image to locate areas of interest. Temperatures can be found at any location on the map. Figure 7 shows a processed image of all three traction motors from one of the FAST locomotives.

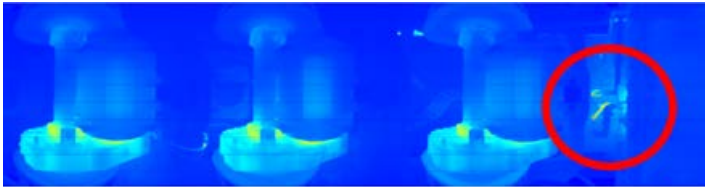


Figure 7. Example processed image from Supplier 2

The color gradient in this image represents about an 85°F range from violet to red. All components are within normal operating range, although the power cables on traction motor 3 (red circle) are shown to be a few degrees higher than the others.

This supplier is completing component identification algorithms that make it possible to trend temperatures on individual components. From the thermocouple validation, a direct correlation is observed between the synchronized thermocouple average readings and the temperatures measured by the thermal camera. Figure 8 shows the heat map with the location of the thermocouple marked and Figure 9 shows the temperature correlation between the thermocouple average data (green) and the LUTIS readings (orange) for that location. Agreement is consistently within 1°C.

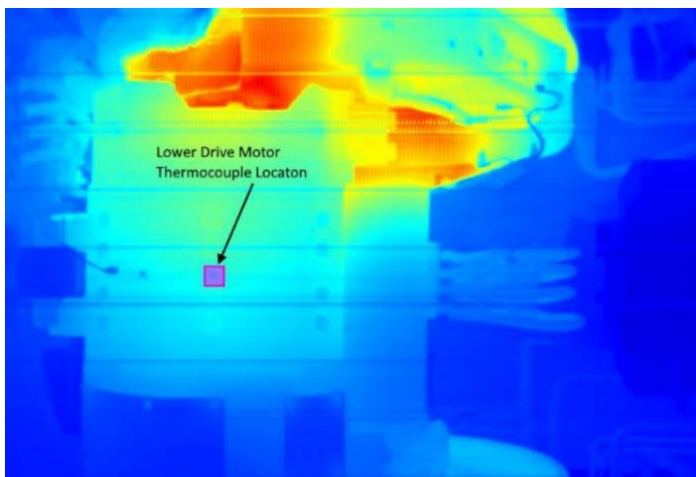


Figure 8. Location of thermocouple on the traction motor

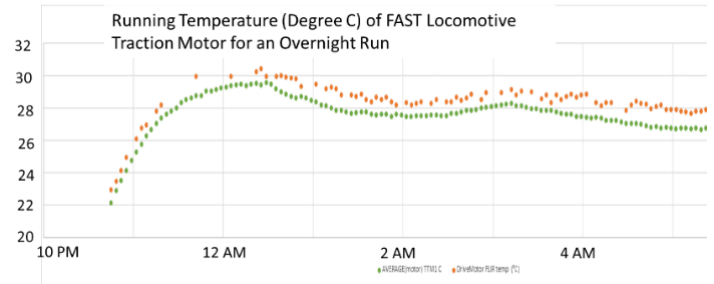


Figure 9. Mapping of TC and LUTIS data for the traction motor for one night of FAST operations

CONCLUSIONS

Two companies are developing LUTIS systems for monitoring locomotive undercarriage components. Thermal accuracy of the systems is verified for both alert sensing of hot components and trending of component temperatures. Development is underway by the system vendors to automate the systems.

PATH FORWARD

TTCI recommends testing of LUTIS in revenue service. The thermal imaging made possible by this technology provides insights into equipment condition that have not previously been available. Revenue service testing would help to better define optimal distribution and placement of these systems for effective monitoring.

For comments or questions about this publication, contact

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