

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

Performance of No. 20 Frogs of Various Designs in Revenue Service

Rafael Jimenez, David Davis, Xinggao Shu, and Ivan Aragona

Summary

Transportation Technology Center, Inc. (TTCI) is evaluating the performance of four No. 20 frogs on the Norfolk Southern as part of the jointly funded Association of American Railroads and Federal Railroad Administration Revenue Service Test Program. Two standard frog systems used by the host railroad and two premium frog systems were installed specifically for this test over a 54-mile section of track south of Lexington, Kentucky, between March and August, 2013. As of April 1, 2016, the frogs have been in service between 226 and 234 million gross tons (MGT).

Findings

1. The heavy points of the premium frogs had about 70 percent less deformation than the points of the standard frogs under the same traffic as of September 2015, when the last measurements were taken.
2. The mainline route wings of the premium frogs had about 33 percent less deformation than the mainline route wings of the standard frogs. Over time, the location of maximum running surface height loss for subsequent measurement cycles on the standard frog wings moved in the same direction (away from the point of frog) and at the same rate (about 6.5 inches per 100 MGT) as their point slopes. On the premium frog at South Fork, maximum height loss occurred between 12 and 14 inches past the point of frog in three of the four measurement cycles. Maximum height loss on the premium frog at Kings Mountain occurred more randomly between 16 and 24 inches past the point of frog.
3. The migratory behavior of the point slopes and wings of the standard frogs, where the effective wheel transfer zone moved away from the point of frog as a function of tonnage, may diminish the chances of either the point or wing suffering a fatigue failure. Conversely, the rapid wear may lead to a wear failure.
4. The design of the frog heel/frog heel-rail interface on the premium frogs reduced running surface deformation by about 50 percent as compared to the standard frog heel designs.
5. The dynamic service environment measurements indicate a generally less severe condition over the premium frogs.
6. The standard and premium frogs have performed similarly thus far in terms of required preventive maintenance.
7. The point of the premium frog at Kings Mountain required weld repair after 167 MGT.

The four frogs remain in service. A life cycle cost analysis can be conducted after the full service life of the frogs is determined.



Please contact **Rafael Jimenez (719) 584-0691** with questions or concerns regarding this
Technology Digest. E-mail: rafael.jimenez@ttci.aar.com.

©2016 Transportation Technology Center, Inc. Unauthorized duplication or distribution prohibited.



INTRODUCTION

TTCI is evaluating the performance of four No. 20 frogs on the Norfolk Southern (NS) as part of the jointly funded AAR/FRA Revenue Service Test Program. The four frog systems were installed specifically for this test over a 54-mile section of track south of Lexington, Kentucky, between March and August, 2013.

The primary determination of performance is based on visual inspection, required maintenance, and wear/deformation of the running surfaces as a function of tonnage. These three parameters were observed and measured during each of the six trips to the test sites. Dynamic response measurements were taken at selected locations of each of the frogs under multiple passing trains during the week of September 29, 2015, to characterize the service environment.

This *Technology Digest* summarizes the tests and results; the detailed results will follow in an AAR Research Summary report.

FROG SYSTEMS TESTED

Each frog is defined as a system because there are several differences among them, including: the type of plates, under-plate pads, heel connections, type of frog point, and others. The frogs were installed as panels in new ballast.

Table 1 lists the four frogs and their corresponding features and components. The frogs installed at Bishop and Corman are of the NS standard design; the frogs installed at South Fork and Kings Mountain are commonly referred to as premium frogs. All the frogs were provided by the same manufacturer.

Measurements

Static

The wear/deformation of the running surfaces on the wings and points of the four frogs was monitored using cross-sectional profile measurements taken with a rail profilometer. A total of 49 profile measurements, mostly at 2-inch increments, were taken at each frog during each of six inspection trips (16 along each of the two wings and 17 along the point).

The following static measurements were taken concurrently with the dynamic response tests: (a) top of rail elevation using a survey level to characterize the overall vertical geometry along the frogs, and (b) longitudinal profile using a straight edge and a digital depth gauge at 1-inch increments over 37 inches along the frog heel/frog heel-rail interface to focus in on the vertical geometry at these specific locations.

Dynamic

Test setup, data collection, and teardowns for the dynamic characterization of the four frogs were conducted over four consecutive days, one frog per day. Each frog, therefore, was measured under a different set of trains.

Acceleration and vertical displacement responses to train traffic in facing- and trailing-point directions and over the straight and diverging routes were captured at the four frogs. The instrumentation was installed at the wheel transfer zones of: (a) the frog wing/frog point interface (Figure 1) and (b) the frog heel/frog heel-rail interface.

Table 1. Frog systems in test, their features and components

Design Feature	NS-Standard Frogs		Premium Frogs	
Location	Bishop (MP 85.6) Northbound: FacingPoint	Corman (MP 95.7) Northbound: TrailingPoint	South Fork (MP 134.8) Northbound: FacingPoint	Kings Mountain (MP 139.1) Northbound: TrailingPoint
Installation Date	4/1/13	3/18/13	8/26/13	
Point Thickness	Standard	Standard	Heavy point 31/32@ 5/8	Heavy point 31/32@ 5/8
Under-Plate Rubber Pads	No	Yes	No	No
Point Slope	10	10	15	15
Frog Running Surface Profile	Flat	Flat	Conformal	Conformal
Heel Design	30° cut, bolted	30° cut, bolted	Miter cut, low impact	Welded heel rails
Frog Heel Plates	4-tie	4-tie	4-tie	4-tie
Frog Plates (Rest)	Single	Single	2-tie	2-tie
Gage Plates	None	None	3	None
Guard Rail Type	C-clamp	C-clamp	Independent, raised 1-1/2"	Independent, raised 2"
Guard Rail Length	26'	26'	26'	26'

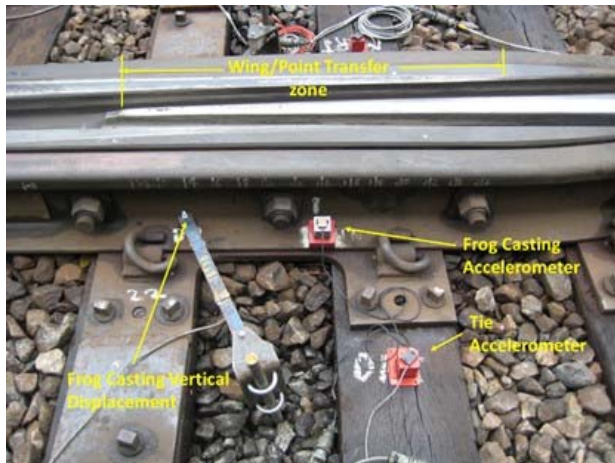


Figure 1. Wheel transfer zone at the frog wing/frog point interface: Instrumentation installed to measure acceleration and vertical displacement.

Each frog side of the wheel transfer zone locations was fitted with (a) one frog base-mounted accelerometer, (b) one tie-mounted accelerometer, and (c) one vertical displacement bending beam. Baseline acceleration, vertical displacement, and vertical wheel load measurement instrumentation was installed in open track, 75 feet past the last long switch tie.

Test Results

Components Wear/Deformation

The longitudinal profiles of the frog points and wings were plotted for each measurement cycle to monitor and compare the degradation of these running surfaces. The longitudinal profiles were derived from the cross-sectional profiles taken along these frog components. The frog point longitudinal profiles consist of the vertical dimensions taken from the bottom of the flangeway gap up to the tip of the point at 2-inch intervals.

Figure 2 shows the total height loss at the tip of the frog point between 14 inches and 46 inches past the theoretical point of frog (between 4 inches and 36 inches past 1/2-inch point of frog) as of the last measurements taken on September 30, 2015. The results indicate about 3.5 times more wear on the standard frogs than on the premium frogs at 16 inches past the 1/2-inch point of frog. The majority of wear (not shown here) on the wings of the four frogs along the mainline route occurred at 14 inches past the 1/2-inch point of frog. The average total height loss measured on the premium frogs at this location is ~0.09 inch; the average total height loss measured at the standard frogs is ~0.14 inch, which is ~1.5 times more than the premium frogs.

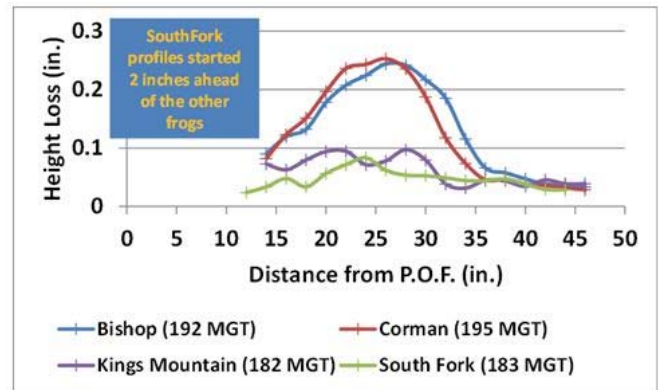


Figure 2. Total height loss along the frog points

Track Geometry Characterization (Static, Unloaded)

The top of rail elevation measurements indicated a 1 percent grade at the frogs at Kings Mountain and South Fork; 0.4 percent grade at the frog at Corman; and 0.2 percent grade at the frog at Bishop. The largest cross level variation was 0.9 inch measured at the heel connection of the frog at Bishop.

The longitudinal profiles measured at the wheel transfer zone over the frog heel indicated that the smoothest transition was the welded connection of the premium frog at Kings Mountain, where the dip along the 37-inch zone was about 0.06 inch. The dip at the miter-cut, low-impact, bolted connection of the premium frog at South Fork was about 0.08 inch. The 30-degree cut, bolted connections of the standard frogs at Bishop and Corman dipped about 0.17- and 0.15-inch, respectively. The longitudinal profiles are illustrated in Figure 3, which shows the curves separated vertically for clarity.

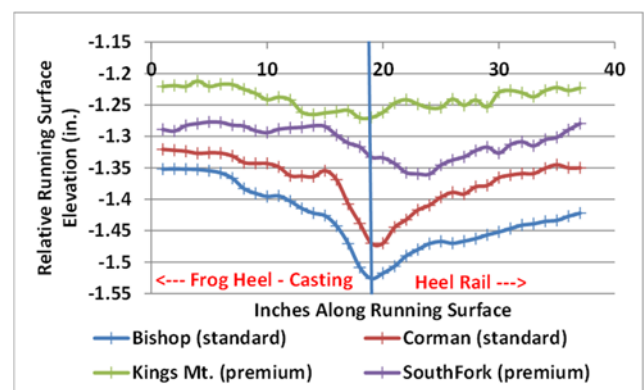


Figure 3. Longitudinal profiles along the frog heel/frog heel-rail interface

Dynamic Service-Environment Characterization

Trains on this mainline transport a wide variety of mixed freight consisting of grain hoppers, coil wire, trailers, containers, tanks, etc., both loaded and empty, and result in a wide range of dynamic wheel loading. Therefore, only the response from the more consistently loaded locomotive wheels was used to derive the results presented here. The frog-side wheels of the three lead 6-axle locomotives of each train traveling on the mainline route in both facing- and trailing-point directions were used, resulting in the following total sample population: 134 locomotive wheels from 15 trains (some wheel data was not usable). The results are presented as the median of the peaks of each channel (acceleration and displacement). Confidence intervals of 95 percent are used to represent the range of the results at each location per frog type and speed. Median values are used instead of mean because the data is not normally distributed.

A comparison of standard and premium frogs acceleration measured at the wheel transfer zone over the frog point is shown in Figure 4. The graph indicates a generally less severe dynamic environment was measured on the premium frogs. In four of the five cases where a premium frog acceleration dataset corresponds with a standard frog dataset at the same speed or occurs at a higher speed, the median premium frog acceleration measured was from 7 g to 20 g lower. The highest median acceleration measured on standard frogs was 96 g at 44 mph; the highest measured on premium frogs was 56 g at 43 mph.

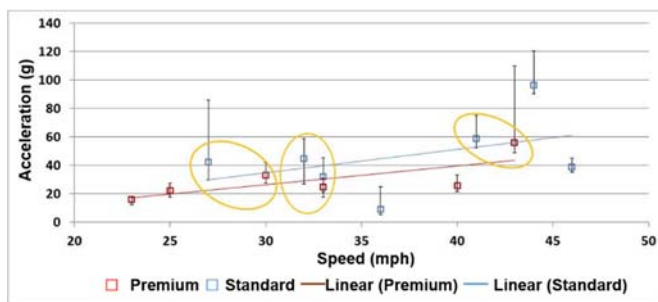


Figure 4. Acceleration – wheel transfer zone over the frog point of the standard and premium frogs along the mainline route

Figure 5 indicates that the vertical displacement measured at the wheel transfer zone over the frog point was also generally less in the premium frogs than in the standard frogs tested. In all cases where a premium frog displacement dataset corresponds with a standard frog dataset at the same speed or occurs at a higher speed, the median premium frog displacement measured was from ~0.14 inch to 0.22 inch less. Comparisons of the regression line through the standard and the premium frog displacement data curves indicate a 2:1 (standard:premium) slope ratio, which suggests that the premium frogs tested were less affected by train speed than the standard frogs. The highest median vertical displacement measured on standard frogs was 0.43 inch at 44 mph; the highest measured on premium frogs was 0.24 inch at 43 mph.

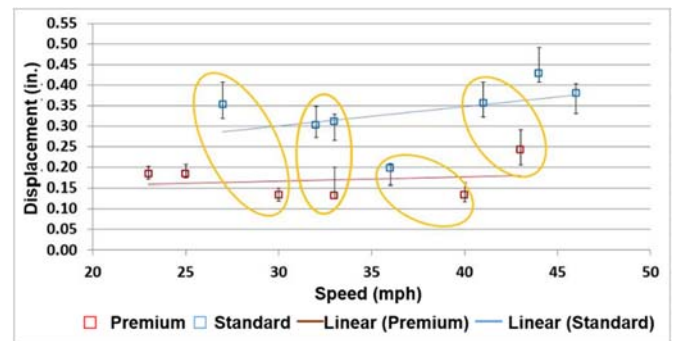


Figure 5. Vertical Displacement – wheel transfer zone over the frog point of the standard and premium frogs along the mainline route

Maintenance

The premium and standard frogs have performed similarly thus far in terms of required preventive maintenance, where the majority involved hand grinding to remove metal flow from the frog points. The point of the premium frog at Kings Mountain was the first to be ground for metal flow, and it was weld repaired to remove running surface damage in the area between 14 inches and 22 inches past 1/2-inch point of frog after about 167 MGT.

ACKNOWLEDGEMENT

TTCI thanks the local NS track crew for supporting the test activities and Gary Click (voestalpine Nortrak) for arranging the donation of its premium test frogs. This project is jointly funded by AAR and FRA.

Visit our website at <http://www.tci.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.