

**Suggested Distribution:**

- Maintenance of Way
- Operating/Mechanical
- Track Maintenance
- Safety

## TOP-OF-RAIL LUBRICATION ENERGY TESTS

by Richard Reiff

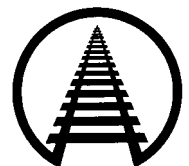
### Summary


Tests of a new top-of-rail lubrication system have demonstrated that this concept is capable of significantly reducing the amount of energy required to move a train. However, during trials, wheel-slip occurred after the third to fifth train pass. This wheel-slip might be eliminated or reduced by adjusting the application rate of the lubricant, or further developing the lubricant to ensure dissipation under the train.

The objective of this demonstration was to document energy and lateral force (truck curving) reductions from lubricating the top of rail behind locomotive(s). The top-of-rail lubricant is metered and applied with the intention that it will be consumed within the train and will not leave a residual trace on top of the rail after the last car. Any residual lubrication might result in reduced adhesion under leading locomotives of following trains.

Top-of-rail lubrication provided a reduction in train energy of up to 30 percent and resulted in significant reduction of lateral loads applied to the rail. Average of maximum lateral forces developed on a 7.5-degree curve reduced from 16.5 kips to 5.2 kips on the inside (low rail), and from 13.3 to 6.9 kips on the outside (high) rail. Certain car trucks termed bad actors, however, exhibited a significant increase in maximum angle of attack when lubrication was applied to the top of both rails. This increased angle of attack did not, however, result in increased lateral loads.

The SENTRAEN 2000 top-of-rail lubrication system produced by Tranergy Corporation was evaluated during June, 1997. The tests were conducted at the Federal Railroad Administration's (FRA) Transportation Technology Center, and funded by the FRA, the United States Department of Energy, and the Association of American Railroads. Norfolk Southern, Union Pacific, Illinois Central, and Burlington Northern Santa Fe railroads pooled their resources to provide locomotives, cars, and engineering staff support. They also assisted in the demonstration of this system.



Work performed by  **Transportation  
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## INTRODUCTION AND CONCLUSIONS

Tests of the SENTRAEN 2000 top-of-rail lubrication system have demonstrated the technology to be effective in reducing the amount of energy required to move a train. However, during trials, wheel-slip occurred after the third to fifth train pass, possibly due to a too-high rate of lubricant application. This wheel-slip may be eliminated by reducing the application rate of the lubricant, or formulating the lubricant to dissipate under a single train.

Top-of-rail lubrication also resulted in significant reduction of lateral loads applied to the rail. Average of maximum lateral forces developed on a 7.5-degree curve reduced from 16.5 kips to 5.2 kips on the inside (low rail), and from 13.3 to 6.9 kips on the outside (high) rail. Certain car trucks termed "bad actors," however, exhibited a significant increase in maximum angle of attack when lubrication was applied to the top of both rails. This increased angle of attack did not, however, result in increased lateral loads.

The tests were conducted at the Federal Railroad Administration's (FRA) Transportation Technology Center in June of 1997, and were funded by the FRA, the United States Department of Energy, and the Association of American Railroads (AAR). Resources, locomotives, cars, and engineering support staff were provided by Norfolk Southern, Union Pacific, Illinois Central, and Burlington Northern Santa Fe railroads, which also assisted in the demonstration of this system. The SENTRAEN 2000 top-of-rail lubrication system evaluated was produced by Tranergy Corporation.

## BACKGROUND AND DISCUSSION

Conventional wisdom decrees that lubrication should be applied only to the rail gage face or wheel flange and to limit applying any lubricant to the top of rail or wheel tread. Traditional lubrication systems strive to carefully apply lubricant only to wheel flanges and/or the gage face of rail, but must contend with the tendency for lubricants to migrate to other parts of the rail, usually in an uncontrolled fashion. Experiments to date with solid-stick type lubricants have shown that these products can offer advantages of reduced tendency to migrate, but application rates and product durability in the heavy freight world have yet to be proven.

Top-of-rail lubrication is applied to the railtop and does not rely on uncontrolled migration. This concept is based on obtaining reductions in energy, due to rolling resistance, and wheel/rail curving forces, by

reducing friction on top of the rail. Any savings from gage-face lubrication is secondary in nature. For this concept to be practical, however, the proper lubricant type and amount must be applied behind the last locomotive with all significant lubricant traces removed by the end of the train. This results in energy savings by reducing trailing-consist friction while maintaining tractive effort for locomotives of following trains.

## TEST RESULTS

Top-of-rail lubrication tests at TTC demonstrated the ability to provide significant reductions in train energy and lateral wheel/rail loads on curved track. However, the concept demonstrated a condition whereby every train was equipped with an operating top-of-rail system. This proved to not be feasible for implementation into revenue service because the residue following the passing of each train resulted in locomotive wheel-slip and train-handling problems with following trains. The test train consisted of three SD60 locomotives and 56 loaded cars. Results indicate that when the top-of-rail system was activated, locomotive electrical (traction motor) energy required to maintain the same train speed was reduced by 23 to 30 percent, while lateral forces at the wheel-to-rail interface were reduced by at least 50 percent when compared with dry (no lubrication) track. Certain cars in the train, which contained worn (but within safety wear limits) trucks, exhibited very high angles of attack (likely a result of excessive truck skewing), during the top-of-rail lubrication application phases. Other performance issues such as train braking, truck hunting, and energy savings obtainable under extended operation were not evaluated.

The Tranergy system used in this test is a proprietary package which incorporates a sophisticated control and application system that uses a special Texaco lubricant. The control system utilizes a number of information sources that measure or specify train speed, curvature, ambient temperature, and trailing tonnage to meter a prescribed amount of lubricant to the top of each rail. Under a scenario of full top-of-rail implementation, applicators would be installed at both ends of all locomotives, with the applicator system software determining which is the trailing end of the last locomotive. Only this last applicator would be activated and used for lubricating the trailing cars of that individual train.

The carefully metered amount of lubricant is intended to reduce friction only within the train being lubricated, thus leaving a dry railtop behind the last car



of the train. For this concept to result in a systemwide energy savings, the last locomotive of every train must be equipped with an operating top-of-rail system.

A large database consisting of wayside and onboard data was collected to support this demonstration (Reiff, Gage, Kumar, FRA Report No. FRA/ORD-98/01, Feb. 1998). A number of test phases of top-of-rail lubricant application were conducted to simulate typical operating conditions. These included dry baseline (no lubrication), flange lubricator only (as a control to identify current practice), top of rail compared to dry rail and compared to contaminated rail. The comparison to dry rail showed changes from a “no lubrication” state, while the contaminated rail condition showed changes from what might be typically seen today on a marginally lubricated railroad segment, with wayside lubricators operating at partial efficiency. An additional phase of this test evaluated mixing top-of-rail and locomotive flange systems. This condition was conducted to simulate what might be observed during the transition period of converting from traditional lubrication of the gage face to a systemwide top-of-rail concept. During such a transition period, both gage face and top of rail would see direct application of lubricant.

The test train was operated averaging 30 mph around a 3.5-mile loop at the TTC’s Facility for Accelerated Service Testing on a section of track with 3-, 4-, 5-, 7.5-, 10-, and 12-degree curves. For much of the time, the train was operating on an average 0.5-percent upgrade with a short 2-percent downgrade. For purposes of determining potential energy savings, negative forces generated in buff have been ignored, as conventional diesel-electric locomotives waste this energy in the form of dynamic brake heat. Exhibit 1 summarizes potential reduction in energy from a dry (baseline) condition for the various lubrication simulations. Electrical data was measured on the No. 2 traction motor of each locomotive, while mechanical energy was measured using an instrumented coupler located in the first car of the train.

The difference between electrical and drawbar energy savings can be explained by their measurement location. The total electrical energy required to move the train is higher than that measured at the lead car drawbar. Electrical energy includes work needed to move the locomotives and train, while drawbar energy represents only that used by the trailing tonnage. The difference between drawbar and electrical energy savings will be verified during future tests when improved control of lubricant prevents an end-of-train

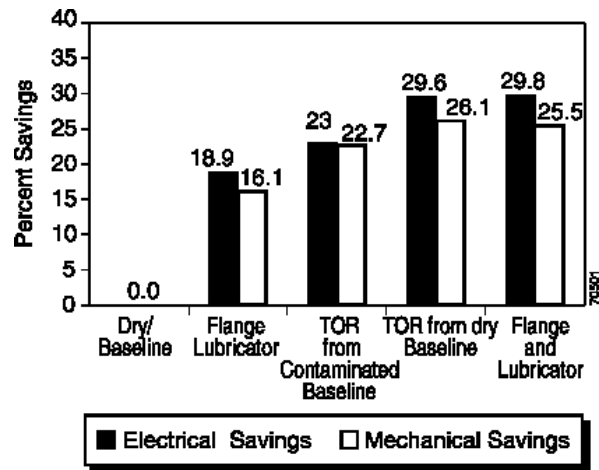


Exhibit 1. Energy Savings Compared to Dry Rail and Contaminated Rail

residual buildup.

Data suggests that top-of-rail lubrication can provide savings in energy greater than that achieved using conventional flange systems; however, by mixing both flange and top-of-rail, no additive effect is seen. Operations could not be maintained for more than five to seven train passes when the top-of-rail system was active without experiencing locomotive wheel-slip in both power and dynamic brake modes. For this reason, actual energy savings that might be obtainable with a top-of-rail lubrication system in revenue-service applications could not be demonstrated as the system application rate could not be reduced to an acceptable level during these tests.

Exhibit 2 summarizes the effect of lateral curving forces at the rail-to-wheel interface at the 4-degree curve. Examination of this data shows that the highest lateral loads were observed under conventional flange lubrication, followed by dry-rail conditions, while the lowest lateral loads were observed whenever the top-of-rail system was in operation. Extended operation with the top-of-rail system was not conducted due to locomotive wheel-slip occurrences.

Although the addition of lubricant on top of both rails reduced the ability of trucks to steer around curves, the measurement made during the test indicated a lowering of lateral loads. Trucks with large amounts of component wear exhibited the highest angles of attack. Angle-of-attack data collected on the 7.5-degree curve shows that these cars exhibited the lowest angles of attack while operating over dry-rail conditions, while the highest angles of attack were

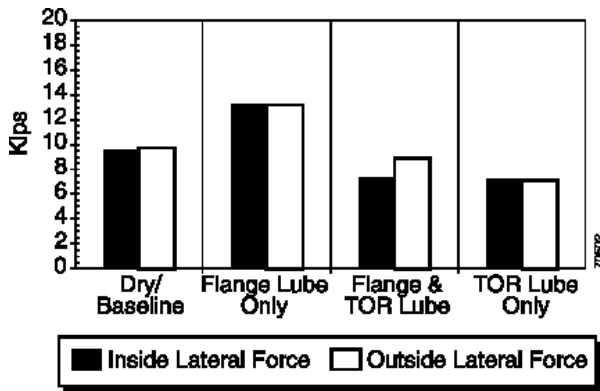


Exhibit 2. Average Lateral Forces on 4-Degree Curve

measured when top-of-rail friction was reduced, as shown in Exhibit 3. Although these cars did not exhibit high lateral loads, such high angles of attack may not be desirable. Similar high angles of attack in other instances have been shown to increase truck-component wear. In addition, high angles of attack increase the potential of derailment at switch points and other special track work.

Additional evaluations of top-of-rail lubrication effects, such as braking and hunting, were not evaluated during this test. Operating the train over a closed loop was intended to simulate a condition where every passing train was equipped with an operating top-of-rail system, which is the intent, if the concept is imple-

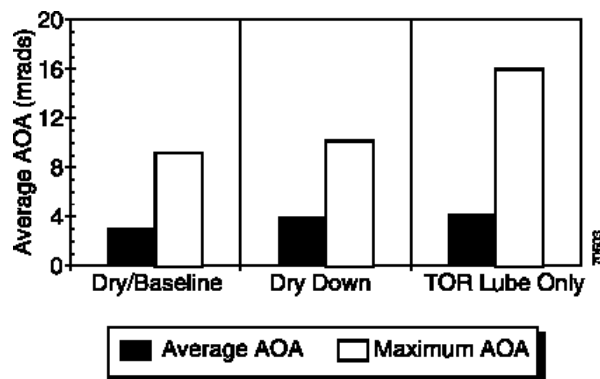


Exhibit 3. Average and Maximum Angle of Attack on 7.5-Degree Curve

mented. Even small traces of lubricant remaining on the rail appeared to be sufficient to allow a buildup, thus after multiple passes a film that inhibited locomotive traction was formed.

### FUTURE WORK

The benefits of the top-of-rail concept are sufficient to warrant further investigation, as well as development of lubricant properties, application rates, and system control. To support this effort Transportation Technology Center, Inc., a subsidiary of the AAR, intends to conduct a demonstration of top-of-rail lubrication systems at the TTC site during mid-1998. Solicitations for participation from vendors and selection of top-of-rail concepts will be screened by the AAR Lubrication Technical Advisory Group and other funding agency representatives. Testing will start with an evaluation stage where lubricant application rates will be optimized by curvature to eliminate the tendency for film build-up after the end of train. The intent of this evaluation will be to determine if the top-of-rail concept is feasible, and if it is possible to control lubrication and prevent train-handling problems and still offer acceptable levels of energy and lateral force reduction. Results from these evaluations will be published as recommended practices for top-of-rail lubrication systems.

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