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## Effects of Friction Control on Fuel Consumption using the Train Energy Model

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### Summary

The Association of American Railroads' (AAR) Train Energy Model (TEM™) was used to predict the energy savings over several revenue service routes using gage face (GF) and top of rail (TOR) friction control systems.

Predicted energy savings are route specific and range from 2.9 percent to 10.6 percent when both systems are active and applying the product correctly over the entire route length.

TOR specific savings dominated the total energy reduction on routes with long tangents and few curves; whereas, in mountainous routes, with mostly curved track, GF systems provided 50 percent of the total savings.

Friction control also provides other benefits, such as reduced rail wear and improved curving forces, which should be considered in the overall economic cost/benefit analysis. Train energy savings predicted from this modeling are site and system specific. While results show significant savings for all route segments modeled, users of TEM must consider the following key limitations.

- Lubrication/friction control is assumed to be uniform and constant for the full distance over the entire route.
- Energy savings shown are PER TRAIN. For mobile-based systems, each train receiving this benefit must be equipped with the proper TOR and/or gage-face application system.
- Users need to consider costs to install, maintain, and operate the appropriate friction control system.
- The existing model assumes a single total reduction in energy from both GF and TOR friction. The split between TOR and GF is based on the percentage of rolling and curving resistance built into the model. Field results from over the road tests validating such savings have yet to be incorporated into the model.

For this evaluation, mobile systems were simulated. Track-based equipment has a specified distance of effectiveness; whereas, vehicle mounted equipment is active for the entire distance simulated.

This work was sponsored by the AAR as part of its Strategic Research Initiatives Program.



## INTRODUCTION

The AAR through its Strategic Research Initiatives (SRI) Program sponsored Transportation Technology Center, Inc. (TTCI) to determine the cost benefits of using TOR friction control as it relates to fuel consumption. For this project, energy consumption was determined using AAR's computer simulation program TEM.

This report details the makeup of the test train, the routes used for comparison, the engineering assumptions, and the results of the simulations.

### Test Train Makeup

For every simulation, the following test train was used:

- Three SD60 locomotives
- Twenty 5-pack double-stack container cars with a gross rail load of 230 tons for a total trailing tonnage of 4600 tons

### Test Routes

The entire test route used for simulation included mainline track from Chicago, IL to Ogden, UT and from Denver to Grand Junction, CO. The two main routes were then broken down into six smaller segments in order to compare results across different types of terrain. Figure 1 shows the six routes used for comparisons.



Figure 1: Map of Routes

1. Chicago, IL – Fremont, NE – 483 miles very little grade or curvature. Average speed of 60 mph
2. Fremont, NE – Cheyenne, WY – 470 miles, very little grade or curvature. Average speed of 60 mph
3. Cheyenne, WY – Laramie, WY – 55 miles, moderate grade and curvature. Average speed 30 mph
4. Laramie, WY – Ogden, UT – 423 miles, moderate grade and curvature. Average speed 55 mph
5. Denver, CO – Dotsero, CO – 170 miles, moderate grade heavy curvature, average speed 27 mph

6. Dotsero, CO – Grand Junction, CO 105 miles, moderate grade heavy curvature. Average speed 45 mph

\*Note: In reality route 5 cannot accept double-stack container cars due to tunnel clearances. This route was used in the model to show the effectiveness of friction control when operating over steep, highly curved mountainous territories.

### Train Energy Model

TEM is a computer simulation program, developed by the AAR, that performs studies of the effects of changes in specific parameters on fuel consumption. These parameters include track geometry, operating speeds, and train makeup. For this evaluation, the only parameters varied were values of rail and wheel friction.

TEM calculates the total resistance on the train throughout the simulation route and then calculates the required energy from the locomotives to overcome the resistance. The total resistance on a train is known to have the following major components:

- Rolling
- Bearing
- Grade
- Curving
- Braking
- Aerodynamic

Of these, only rolling and curving resistances can be reduced by controlling rail and wheel friction. Depending on the terrain, these two resistances account for as little as 9 percent to as much as 50 percent of the total energy consumption.

### Lubrication/Friction Control

For purposes of this study, lubrication is defined as reducing side and gage face (flange/curving) friction, while TOR friction control reduces TOR (rolling) resistance.

Lubrication reduces friction to  $0.2 \mu$  or less, and is intended to only be applied to the side/gage face of rails. Experience has shown, however, that excess lubricant will migrate to the top of the rail and can result in braking and traction problems.

TOR friction control is achieved by applying a friction modifier to the top of rail, which produces an intermediate level of friction ( $\sim 0.35 \mu$ ) to the rolling surface.

Either fixed-location (wayside) or mobile-based (locomotive) application systems can be used to apply these products. While the model can simulate either track-based or vehicle-mounted equipment, for this evaluation mobile systems were simulated. Track-based equipment has a specified distance of effectiveness; whereas, vehicle mounted equipment is active for the entire distance simulated.

The current TEM, regardless if vehicle- or track-based equipment is specified reduces both curving and rolling resistances when lubrication is active. To determine benefits of TOR, reductions in energy predicted by the model were separated for rolling (TOR) and curving (gage face) effectiveness.

For each route, two simulations were performed to compare dry (no friction control of any kind) versus lubricated or TOR conditions. Results were then separated to determine TOR and gage face benefits.

**RESULTS**

The results of the simulations are shown in Tables 1 and 2. For each simulation, the results are shown for both dry and lubricated conditions. In Table 1, the savings stated are a combination of both TOR and GSF lubrication. Savings are shown in three different ways for each section of track.

- Absolute difference in gallons consumed
- Gallons per mile
- Percent of total fuel saved

This allows for a better comparison of the savings depending on the specific route of interest. The data suggests each terrain affords a different savings.

**Table 1. Fuel Savings Per Route**

Route	Distance (mi)	Total Fuel Dry (gal)	Total Fuel Lubed (gal)	Delta (gal)	Savings (gal/mi)	Savings (%)
(1) Chicago-Fremont	483	2334	2170	164	0.34	7.0
(2) Fremont-Cheyenne	470	2998	2807	191	0.41	6.4
(3) Cheyenne-Laramie	55	684	664	20	0.36	2.9
(4) Laramie-Ogden	423	1704	1575	129	0.30	7.6
(5) Denver-Dotsero	170	1571	1496	75	0.44	4.8
(6) Dotsero-Grand Junction	105	218	195	23	0.22	10.6

Table 2 shows details of the savings for the two concepts of friction control. As an example, results suggest the Denver-Dotsero route would gain the most improvement from GF lubrication as compared to the Fremont-Cheyenne route, which would benefit mostly from TOR friction control.

**Table 2. Fuel Savings by Friction Control Concept**

Route	Distance (mi)	Delta (gal)	TOR Delta RR (gal)	GF Delta Curve (gal)
(1) Chicago-Fremont	483	164	157	7
(2) Fremont-Cheyenne	470	191	188	3
(3) Cheyenne-Laramie	55	20	16	4
(4) Laramie-Ogden	423	129	113	16
(5) Denver-Dotsero	170	75	41	34
(6) Dotsero-Grand Junction	105	23	15	8

**Discussion**

Friction control also provides other benefits, such as reduced rail wear and reduced curving forces, which should be considered in the overall economic cost/benefit analysis. Train energy savings predicted from this modeling are site and system specific. While results show significant savings for all route segments modeled, users must consider the following key limitations:

- Lubrication/friction control is assumed to be uniform and constant for the full distance over the entire route.
- Energy savings shown are PER TRAIN. For mobile-based systems, each train receiving this benefit must be equipped with the proper TOR and/or gage-face application system.
- Users need to consider costs to install, maintain, and operate the appropriate friction control system.
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Users implementing wayside based systems can assume the same general savings, but only over the effective distance of the specific friction control system. For example, current recommendations for wayside based TOR suggest an application system is needed every 1.5 to 2 miles, thus the per train energy savings shown would be viable for a 1.5 to 2 mile distance after each wayside applicator site.

## FUTURE

Over the road energy testing of mobile TOR friction control systems is planned by at least one AAR member railroad in 2007. The results will be used to modify the GF and TOR savings mix assumed for this report.

## REFERENCES

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