Locomotive Tractive Effort Tests on Norfolk Southern Railway

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ABSTRACT

This paper describes locomotive tractive effort testing on Norfolk Southern Railway. The purpose was to measure maximum locomotive performance under real-world conditions on wet and dry rail. A variety of DC and AC locomotives were tested, ranging from low power switchers and gensets to high power road units. Typically, two locomotives were used as head-end power, followed by Research Car NS 32 for data collection purposes, and then a number of loaded hoppers that were individually weighed on certified scales. Testing was conducted near Roanoke, VA; the 2.75 mile test segment ascended a 1.38% average grade with a series of four, six and eight degree curves. Loaded hoppers were either added to or cut off the rear as needed to achieve a 10 mph (approx. 16 kph) average speed up the mountain.

1. INTRODUCTION

This paper describes locomotive tractive effort testing on Norfolk Southern Railway. Purpose of the tests was to measure maximum locomotive performance under real-world conditions, to evaluate new power and control system technologies and to weed out the poor performers. An added benefit was the ability to make better locomotive fleet purchasing and re-power decisions. A variety of DC and AC locomotives were tested, ranging from 2000 horsepower (approx. 1500 kW) switchers to high horsepower road units. Locomotives using gensets as the prime mover were also included.

This test characterized locomotive response to wet and dry rail conditions by measuring performance in drag freight operation. Typically, two locomotives were used as head-end power, followed by Research Car NS 32 for data collection purposes, and then a number of loaded hoppers that were individually weighed on certified scales. A locomotive was also used on the rear of the train to facilitate reverse moves down the mountain; this locomotive operated in idle while testing uphill.

Testing was conducted on the NS Virginia Division, Winston-Salem District, near Roanoke, VA; the 2.75 mile test segment ascended a 1.38% average grade with a series of four, six and eight degree curves. Loaded hoppers were either added to or cut off the rear as needed to achieve a 10 mph (approx. 16 kph) average speed up the mountain.

Test results were used to fine-tune wheel slip control software, refine the tonnage ratings of existing locomotive groups, and to help establish accurate trailing tonnage for freight trains. A portion of the results are reported, as tests are still in progress with the remainder of the fleet, including slug sets and hump units.

2. HISTORY OF TRACTIVE EFFORT TESTS

Historically, predecessor railroads have been evaluating the Tractive Effort (TE), or pulling power, of locomotives as long as they have been operating. This has been done in simple fashion by adding cars to a train, making it increasingly heavier until it stalls on a grade, or through more sophisticated methods by using a special passenger car with on-board instrumentation to measure the various aspects of locomotive performance such as power, speed, etc., as it moved down the track. This specialized rolling railroad laboratory was often called a dynamometer car, so-named after the instrumentation used to measure drawbar force. The car also provided quarters for the laboratory crew while testing en route. Coupled directly behind the locomotive, it could be used with light engines, or with a passenger or freight train trailing behind. In early years, they were used to measure steam locomotive performance, but later as railroads converted to diesels, the cars were modified to measure diesel-electrics as well.

Norfolk Southern Railway has a Research and Tests (R&T) Department that is headquartered in Roanoke, VA. The R&T Department operates its own version of a dynamometer car, the Research Car NS 32, and uses it to evaluate the performance of modern diesel-electric locomotives as described above.

3. DATA COLLECTION

The NS 32 Research Car was positioned directly behind the locomotive consist as shown in Figure 1. Onboard computers collected data and monitored train performance during each run up the hill, including track location with GPS, milepost, foot count, train speed, drawbar force, and locomotive electrical and mechanical power. The Research Car is equipped with an instrumented coupler (sometimes referred to as a dynamometer coupler) that measures buff and draft forces.

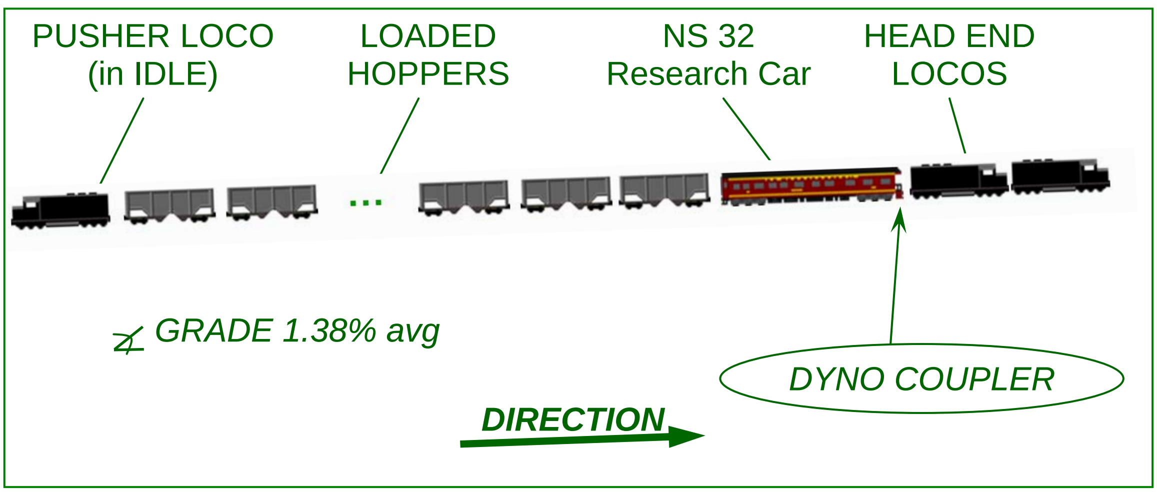

Figure 1. Train Consist Graphic

4. TYPES OF LOCOMOTIVES TESTED

A wide range of locomotives were tested, including:

- DC Models
  - 3000 hp (2200 kW) road locos; genset & conventional prime movers
  - 2000 hp (1500 kW) switcher locos; genset & conventional prime movers
  - Mother + Slug combinations (4-axle)
- AC Models
  - 4000+ hp (3000+ kW) road locos

The train shown in Figure 2 operated with two locomotives on the head end, followed by Research Car NS 32 and loaded hoppers; this consist was the typical setup of most trains tested.

Figure 2. Test Train With Two-Unit Head End, Research Car, Loaded Hoppers

5. TRACK PROFILE OF TEST SEGMENT

The 2.75 mile long (approx. 4.4 km) test segment was on the Norfolk Southern main track between Roanoke, VA and Winston-Salem, NC. It was characterized by a uniform 1.38% average grade (1.56% maximum) and included a series of 4, 6 and 8-degree curves as shown in Figure 3. Speed limit is 25 mph (approx. 40 kph) for freight trains, and it carries 15 MGT (approx. 13.6 M metric tonnes) of traffic annually, mostly unit coal and grain trains.

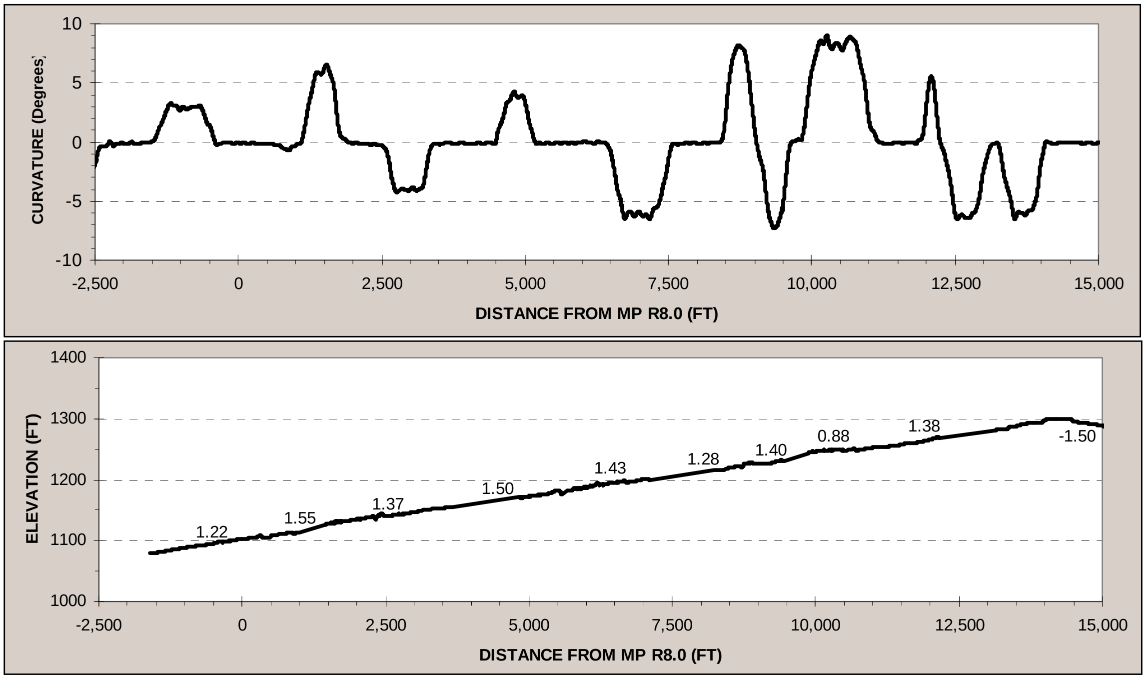

Figure 3. Curvature and Grade of Test Segment

6. WET RAIL SIMULATION

Data were collected with the train operating under two rail head friction conditions - one with the rail head dry or as-is, and the other wet, to simulate rain. To do this, four 55-gallon water tanks were mounted on the lead locomotive. Water from the tanks was then dispensed to the rail through a simple hose-and-pipe arrangement, with the end secured to the sand nozzle bracket. The gravity-fed water flowed out of the pipe and covered the top of the rail ahead of the lead wheel set as shown in Figure 4. The locomotive was configured to apply sand automatically as needed, and the orientation of the water spray was such that the sand was not washed off of the top of the rail. This methodology afforded an operating scenario that most-closely simulated a wet or raining condition, in lieu of other schemes using grease, soap, oil or other lubricants.

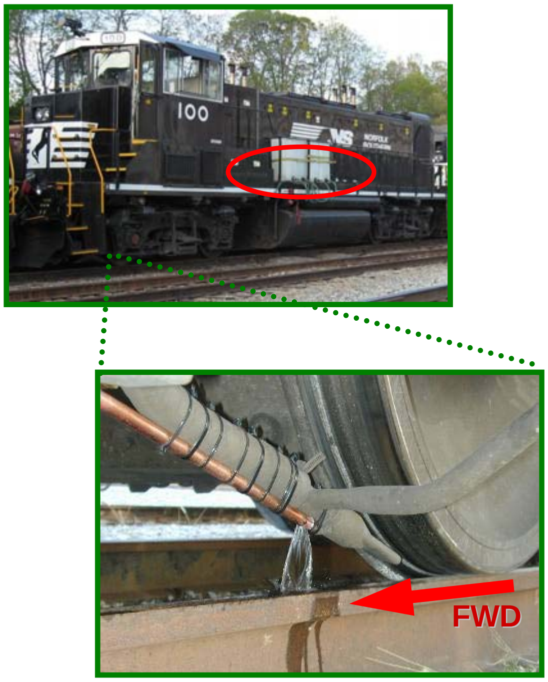

Figure 4. Wet Rail Tanks, Hose, Piping

7. GOOD PERFORMANCE CONFIRMED

Most locomotives performed as anticipated, and test results verified existing freight train tonnage ratings for some of the more powerful road locomotives. Figure 5 shows results from three of these units, with an average and minimum speed range plotted for the corresponding maximum tonnage pulled up the hill. There were two distinct sets of data - one set was clustered around a wet rail mean tonnage, and another more closely centered on a dry rail tonnage. This represents the heaviest tonnage that could be successfully pulled up the hill by a particular type of locomotive for each rail condition.

The existing tonnage rating for these units is 6400 tons (approx. 5800 metric tonnes). Results showed that the wet rail tonnage was 100 to 400 tons (approx. 90 to 360 metric tonnes) greater than rated tonnage, so this was an opportunity to increase the tonnage rating for this group of units. Also interesting to note was the disparity between wet and dry rail tonnages for these units; 7900 tons (approx. 7170 metric tonnes) dry versus 6500 – 6800 tons (approx. 5900 – 6170 metric tonnes) wet. The difference between average and minimum speeds during the test was greater on wet rail than on dry rail, also indicating how well each locomotive was able to handle a worse-case condition of the wet rail surface. In addition, the wet rail tonnage is more heavily weighted than dry rail results for use in establishing an all-weather tonnage rating for a specific locomotive group.

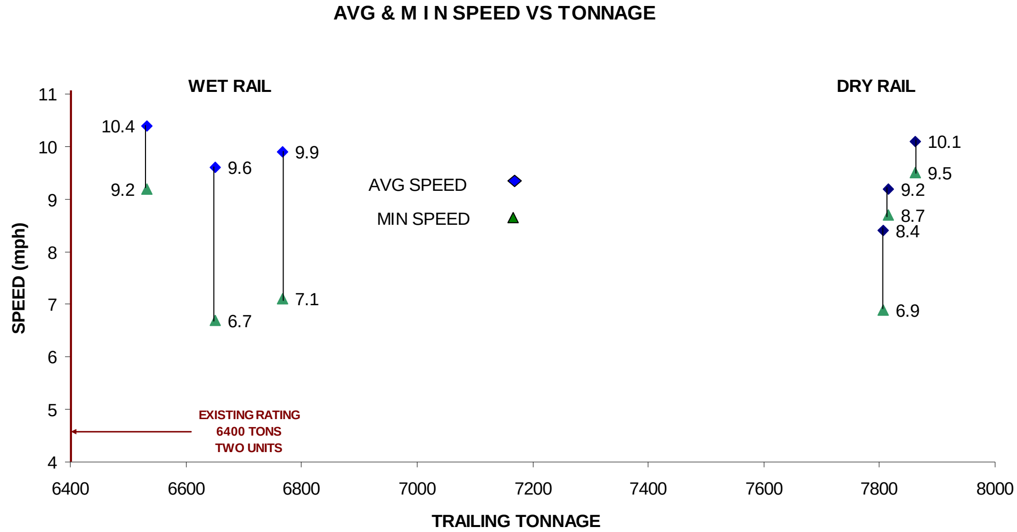

Figure 5. Graph of Average & Minimum Speed Versus Tonnage

8. POOR PERFORMANCE IDENTIFIED AND CORRECTED

Not all results were as favorable as those described above. For example, during a test of a 6-axle road locomotive using two powered units on the head-end, severe wheel slips with up to 50% horsepower de-rating occurred throughout the wet rail tests on both the lead and trail units. Surging drawbar forces produced by cyclic power drop-outs created a potentially dangerous fatigue failure environment for draft system components, and greatly increased the risk of breaking a train in two (Figure 6).

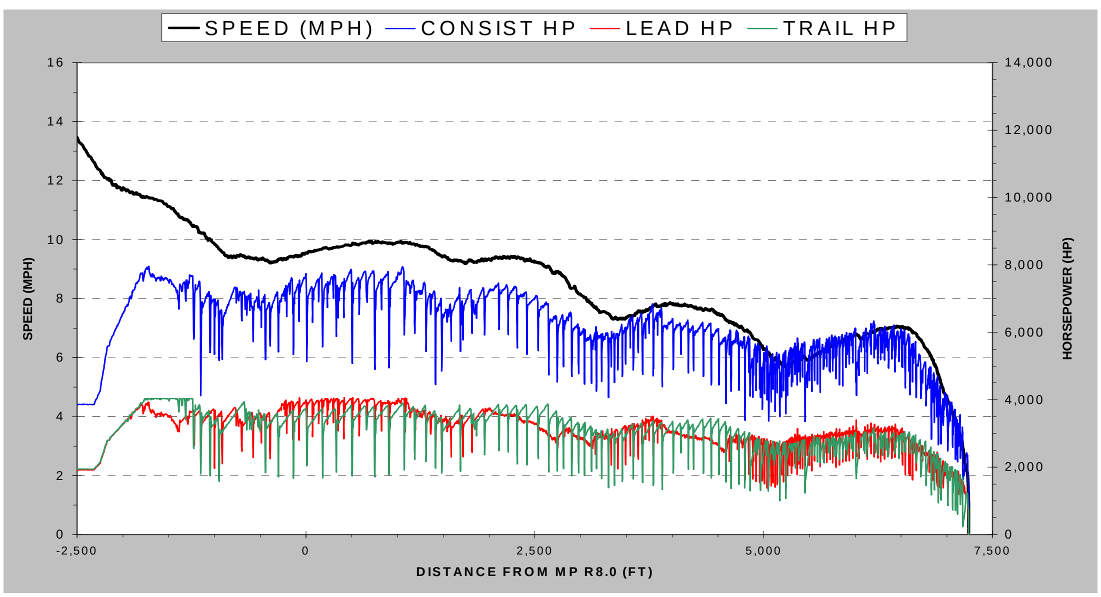

Figure 6. Locomotive Power and Speed Versus Distance

Anecdotal reports submitted by crew members operating these particular units in freight train service described this surging action, but it had never been documented to this level of detail until test. These results were deemed unacceptable, so test results and data files were provided to the manufacturer's engineers who were on-hand during tests. Fortunately, the manufacturer was able to identify the problem and make software and other changes to correct this poor performance. Much-improved satisfactory results were verified in subsequent follow-up tests.

9. TRAILING TONNAGE SET TOO HIGH

Test results on Group "F" locomotives indicated that the existing trailing tonnage limits were set too high. Wet rail results for all three models of units tested in this group were at less than rated tonnage (shown by the red line 7560 tons (6860 metric tonnes) in Figure 7). This led to a slight downward adjustment of the tonnage rating for these units to more accurately reflect the test results and lead to fewer stalls of heavily loaded revenue trains.

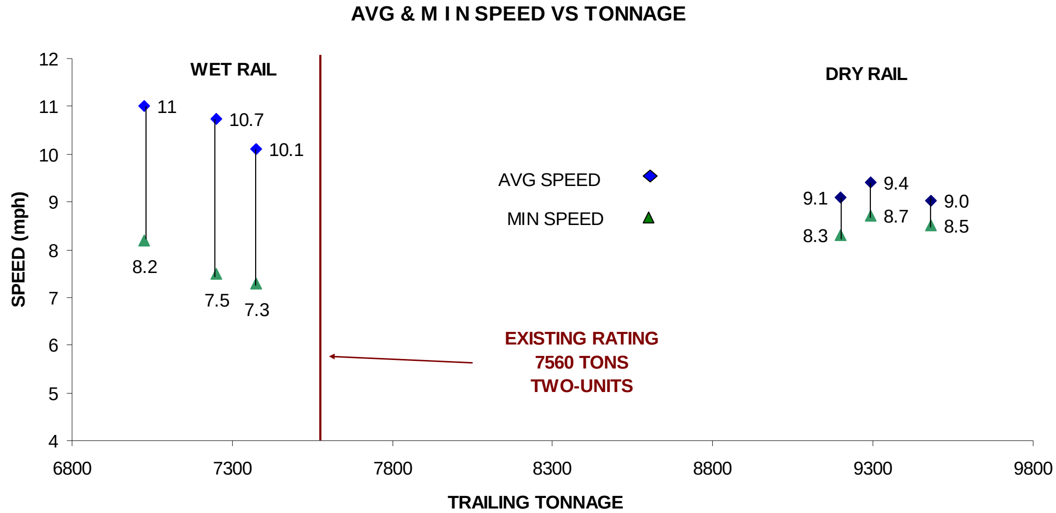

Figure 7. Graph of Average & Minimum Speed Versus Tonnage, Group "F"

Wet rail results of locomotive consists plotted against each other were also very revealing. In Figure 8, final ratings for Group "E" and Group "F" locomotives showed two locomotive models that were of concern – in particular, the worst performers in each group (E1 and F1) were targeted for attention by both the railroad and manufacturer. Changes in software, hardware and/or other components were made and through follow-up tests, the units were brought up to peak performance. Changes were made to others in the same series so that all units in the fleet benefited from the best performance possible.

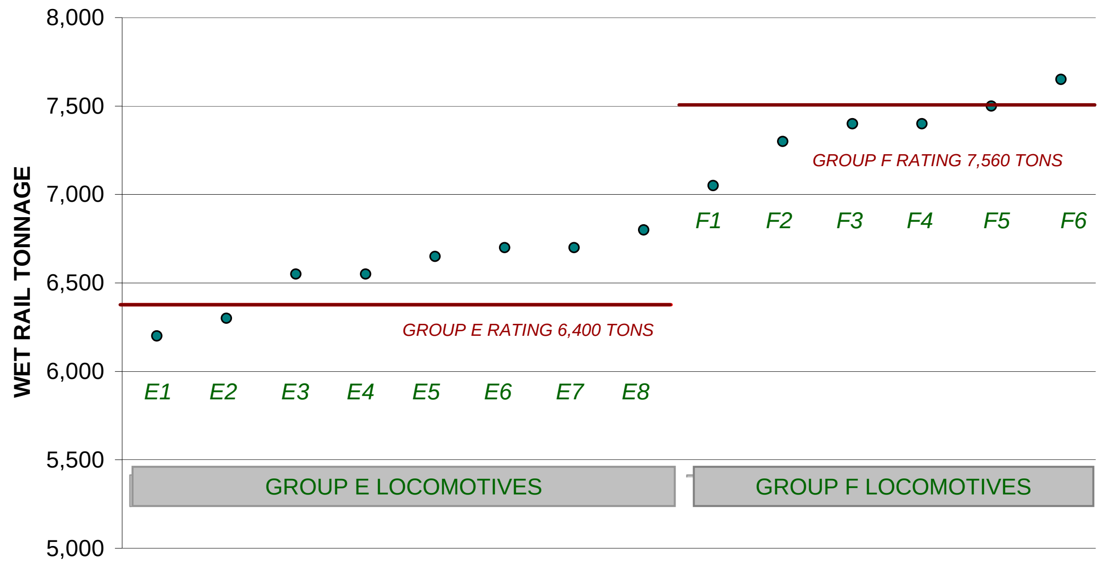

Figure 8. Wet Rail Comparison, Group “E” & Group “F”

10. STARTING TRACTIVE EFFORT

One important aspect of these tests was determining the maximum TE that the locomotives could generate, the so-called “starting TE”. The starting TE is a static measurement, determined by pulling against a train that does not move. In this case, the locomotives pulled against a cut of loaded cars with the airbrakes set such that the train did not move. The rail was dry and sanded to afford the greatest traction. Some locomotives handled this aspect of the test better than others; for example, Figure 9 shows two different locomotives in the same grouping. The poorer-performing consist had drawbar fluctuations greater than 120 kips (approx. 530 kN), while the better-performing consist was steady with less than 50 kips (approx. 220 kN) fluctuation. Changes were made to the poorer-performing locomotives; they were successfully retested and the changes applied to the remainder of those models in the fleet.

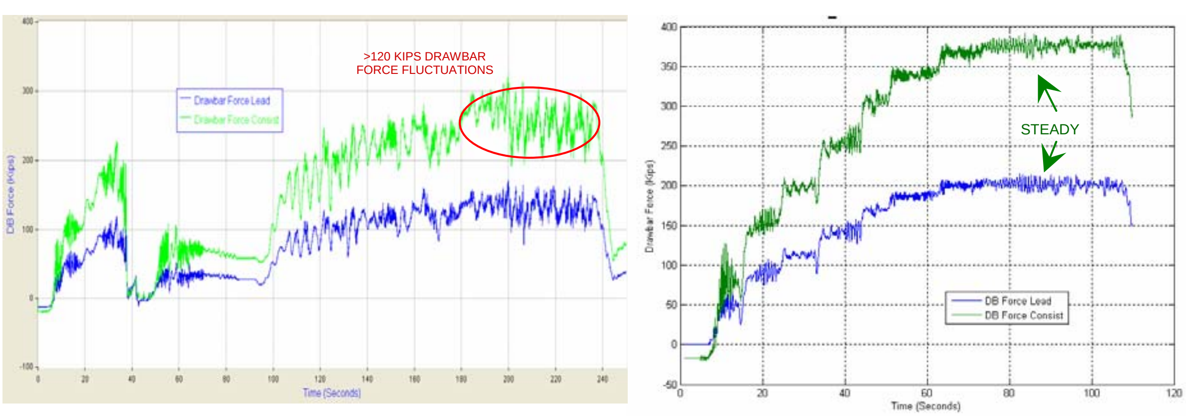

Figure 9. Comparison of Starting TE

Problems with starting TE were not limited to high-adhesion locomotives, as most of the low powered 4-axle units had their share of adhesion problems. In fact, the majority of them failed initial tests in the as-received condition, as five of six models tested did not even complete their initial test run:

1. A1 stalled due to kicking ground fault relay and traction motor overheating during the run;
2. A2 stalled due to wheelslip control issues;
3. A3 stalled due to wheelslip control errors;
4. A4 stalled due to software programming errors;
5. A5 stalled due to engine shut-down.

Most manufacturers claimed/advertised a starting TE and adhesion level for their new locomotives. But it was found that the performance of these locomotives during the starting TE test was not much better than the main line tests on the grade, as only two of six models that were tested performed better than claimed. In Figure 10, a green box around the results indicates *better* than claimed, while a red box indicates *worse* than claimed.

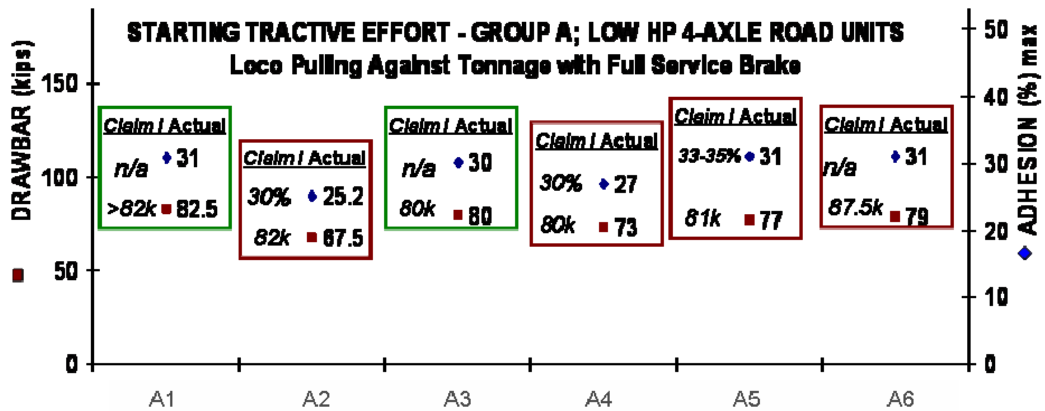

Figure 10. Comparison of Starting TE and Adhesion, 4-Axle Models

In most cases, problems were eventually resolved through OEM engineering field support.

11. CONCLUSION

The current paper describes the methodology and general results of locomotive tractive effort tests. Objectives were to measure locomotive performance under real-world conditions, with the test designed to eliminate as many variables as possible to get comparable results. A portion of the results are reported. These tests are ongoing as NS continues to wring out peak performance of the locomotive fleet.