NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC

April 2, 2019

Force and Motion Study

D.A. Crider

A. ACCIDENT: RRD19FR001

Accident Type:	Train Collision
Location:	Granite Canyon, WY
Date:	October 4, 2018
Time:	Approximately 7:38 P.M. mountain daylight time
Trains:	UP MGRCY04 (striking train) and UP MPCNP03 (stationary train)

B. GROUP IDENTIFICATION:

No group was formed for this activity.

C. SUMMARY

See the Accident Summary Report on the docket for this investigation.

D. DETAILS OF INVESTIGATION

Purpose of Study

The study was done to determine the time history of the motion of the striking train, the buff and draft forces between the cars and to correlate these forces with the state of the train and the level of braking action.

Point of Collision

The collision point (CP) was at milepost 527.12. This corresponded to 41.0996 degrees North latitude and 105.1322 degrees West longitude. For the purpose of this study, actual track miles will be used relative to this point.

Track Data

Union Pacific provided track survey data. Milepost and offset from this data were converted to actual miles with miles aligned with milepost at the collision point. The track survey data is shown on a map in figure 1 with the CP noted. The striking train was east bound (decreasing milepost) at the time of the collision. Elevation is plotted as a function of actual miles in figure 2. With the track data sampled every foot along the track there was considerable noise in derived pitch and other derived parameters. Accordingly, the track data was downsampled to once/50 ft and smoothed.

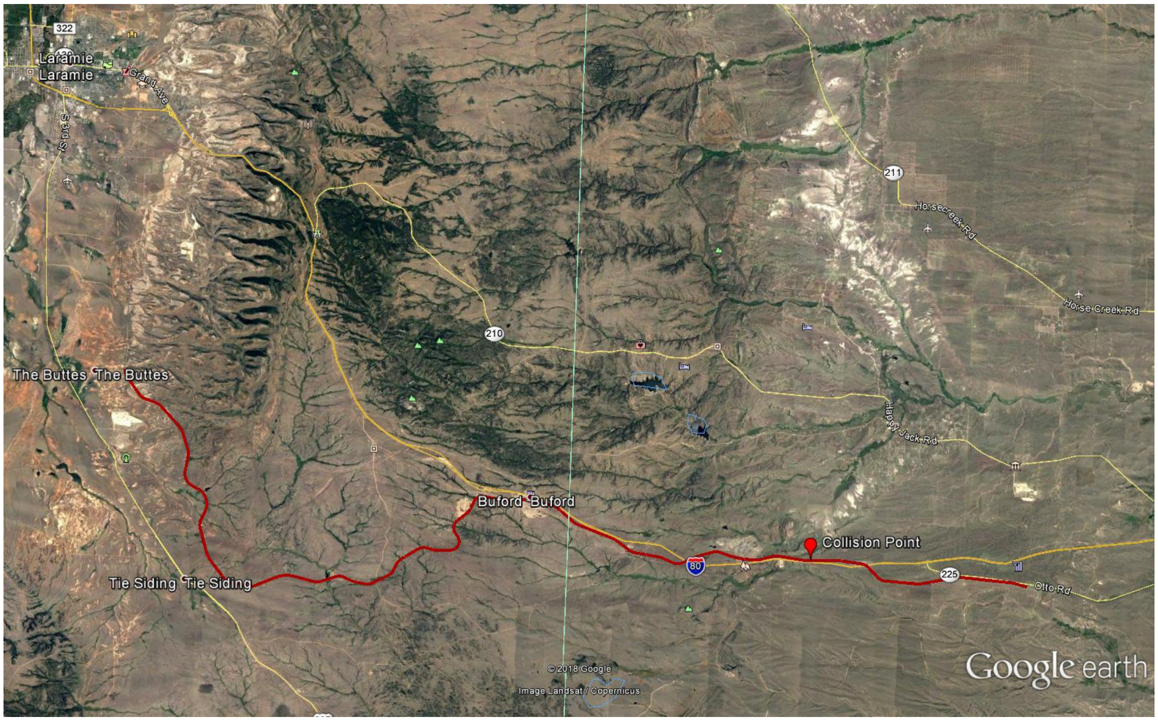

Figure 1 Track Geometry with Collision Point

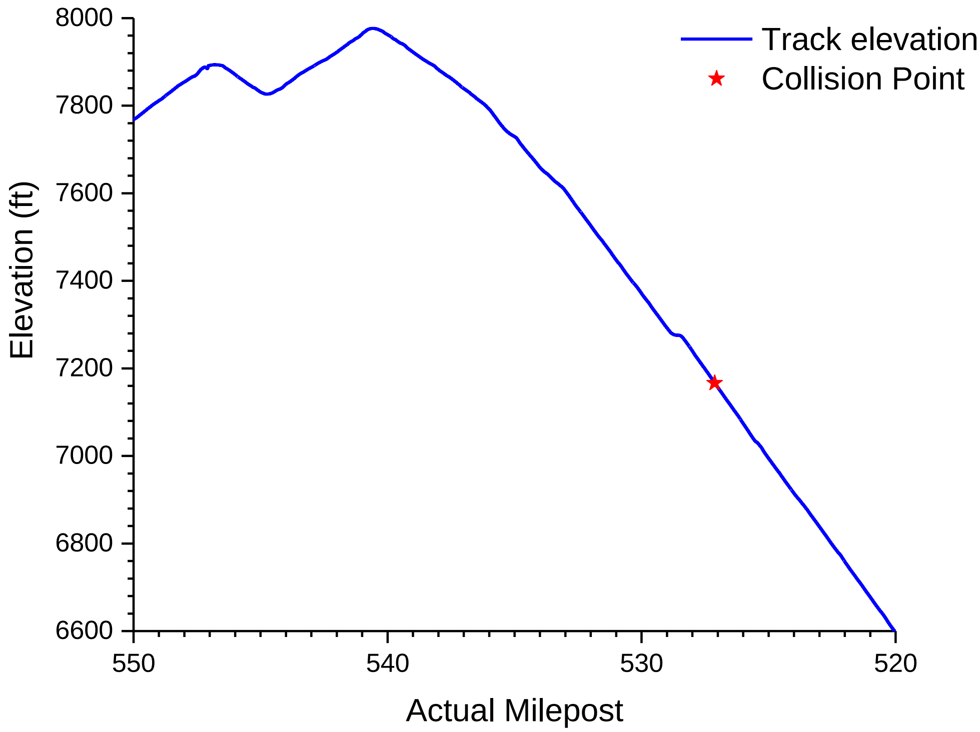

Figure 2 Track elevation

Consist Data

The calculations require the length, weight, and coupler slack for each car or engine in the train. The train consist was obtained and transcribed into the required input geometry file format. The input geometry file for the train is reproduced in Appendix A.

Recorder Data

The train had three locomotives on the head end. The calculations require speed, tractive effort and brake pipe pressure as input. Before proceeding with the calculations, the recorder time prior to the collision was shortened to approximately the last 1 hour 20 minutes for the input parameters so that the entire train would be on the available track segment selected for the analysis. Speed was recorded to the nearest MPH. The miles traveled parameter was recorded with greater precision. Accordingly, speed was obtained by taking the derivative of miles traveled and converting to MPH within the CIDER recorder readout program. This calculated speed was then smoothed with a 25 point 2nd order Salvisky Golay to minimize false accelerations due to data resolution.

This smoothed speed is plotted with the raw speed derived from miles traveled in figure 3.

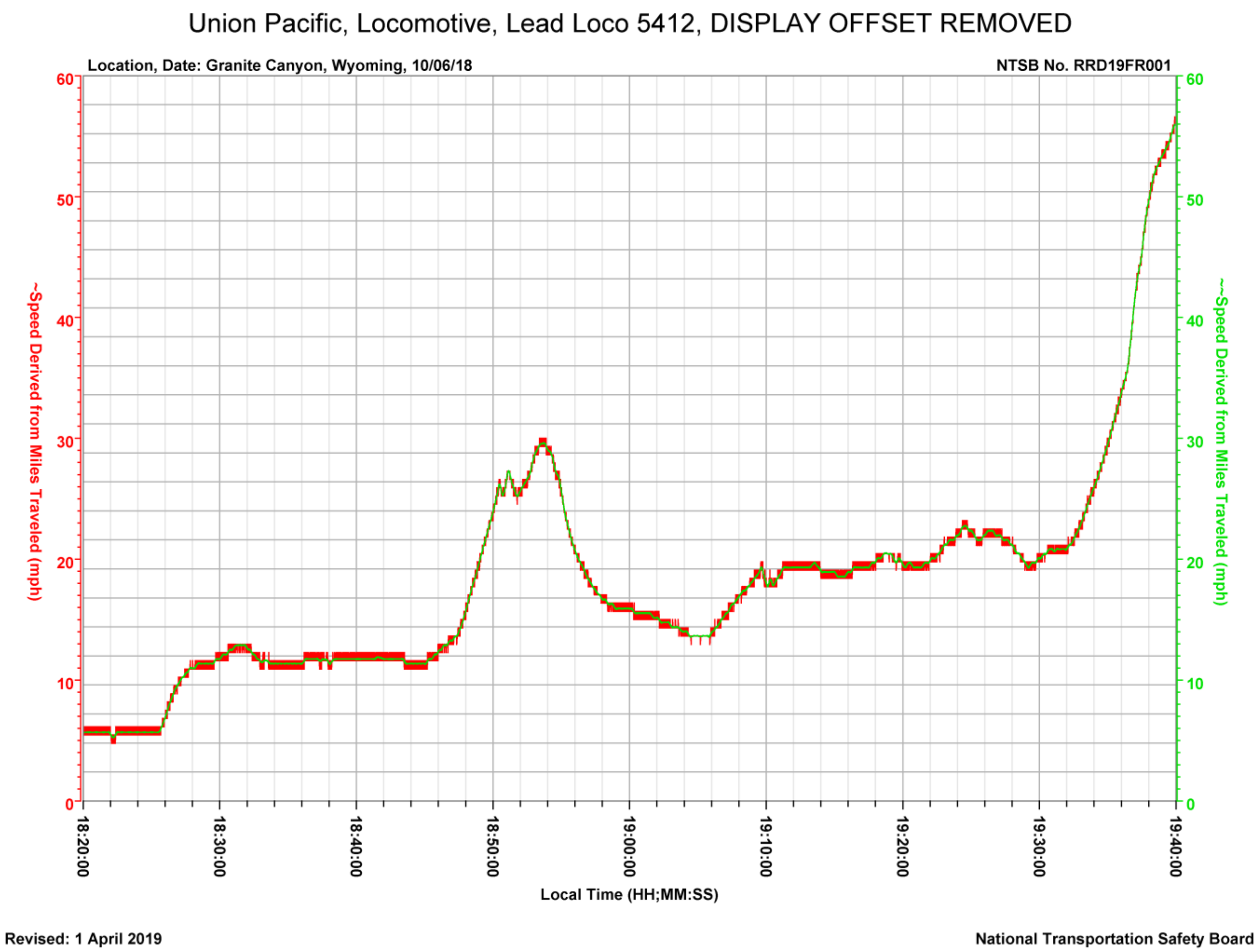

Figure 3 Smoothed speed comparison

When dynamic braking is engaged, it is recorded as positive in the tractive effort parameter. Accordingly, recorded tractive effort was multiplied by negative 1 when dynamic braking was engaged. Recorded tractive effort for the lead locomotive was further multiplied by 1000 to convert to pounds force for the analysis. Tractive effort was not available for the second and third locomotive, but both responded to commands from the lead locomotive. Accordingly, tractive effort for these locomotives was set equal to the tractive effort of the lead locomotive. As can be seen in figure 7 discussed later, this provided an accurate match before the brake failure. Input tractive effort for the three locomotives is shown together with recorded brake pipe pressure in figure 4. Brake pipe pressure is plotted with brake handle position in figure 5.

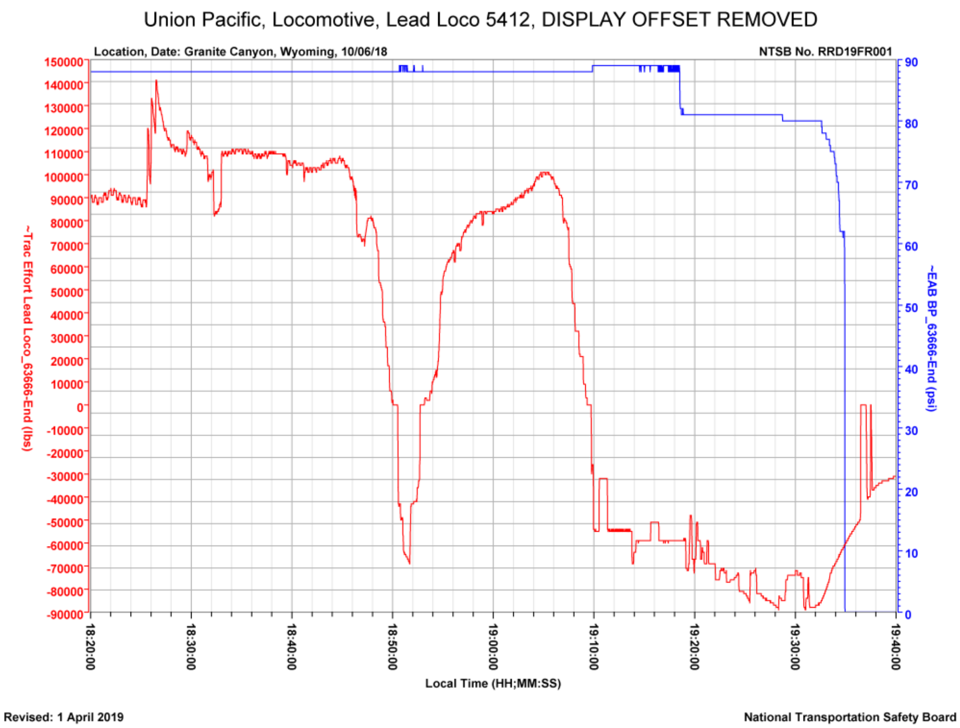

Figure 4 Tractive effort and brake pipe pressure

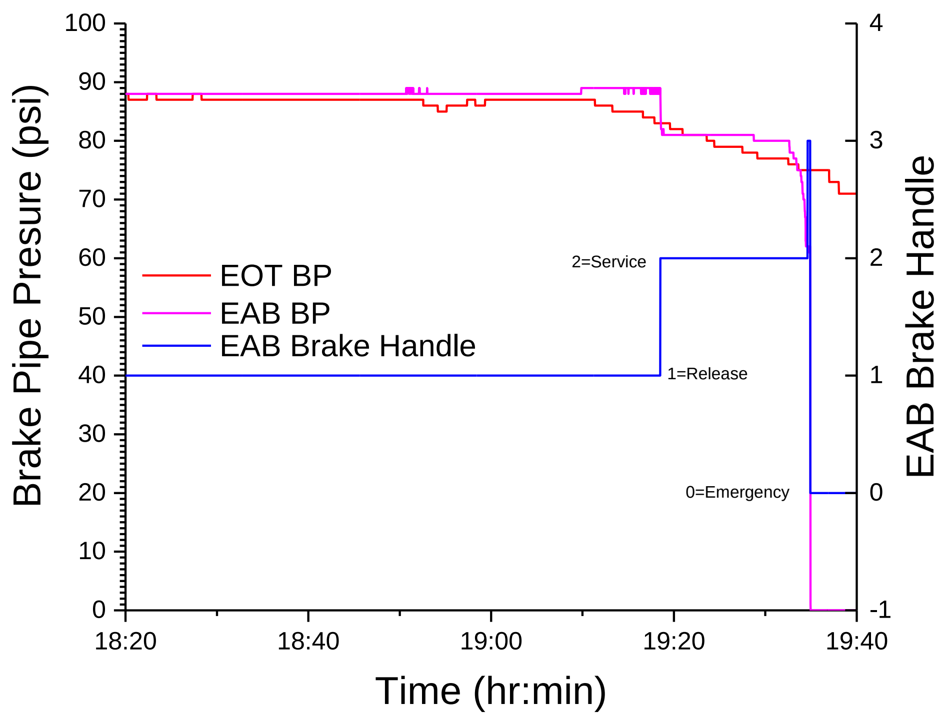

Figure 5 Brake pipe pressure and Brake Handle

Motion Time History

The position time history shown in figure 6 was obtained with a reverse integration of the speed calculated from miles traveled from the collision point (milepost 527.12, 41.0996 degrees North, 105.1322 degrees West). A speed factor of 1.0244 was applied to match the IETMS milepost from the PTC system.

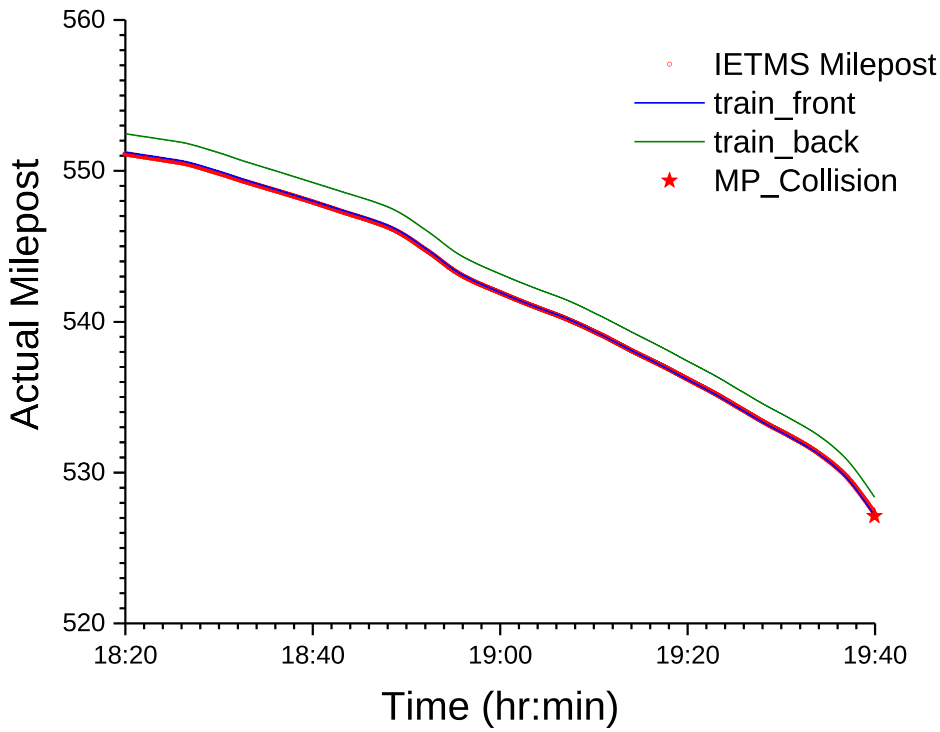

Figure 6 Train position

Buff and Draft Forces on Train

The CIDER/RailPlus program assumes normal brakes in its calculation of coupler forces. Accordingly, these forces are only valid when brakes are working or when brakes are released (service brakes were applied about 19:18 after the brake failure at approximately mile 535).

The CIDER/RailPlus program calculates actual force required for the recorded motion on the track. It also calculates total force commanded (that is the sum of tractive effort from all locomotives and braking force assuming normally functioning air brakes. As can be seen if figure 7, these forces agree well until service brakes were applied at about 19:18:31. As can be readily seen, there was very little retarding force from the brake application.

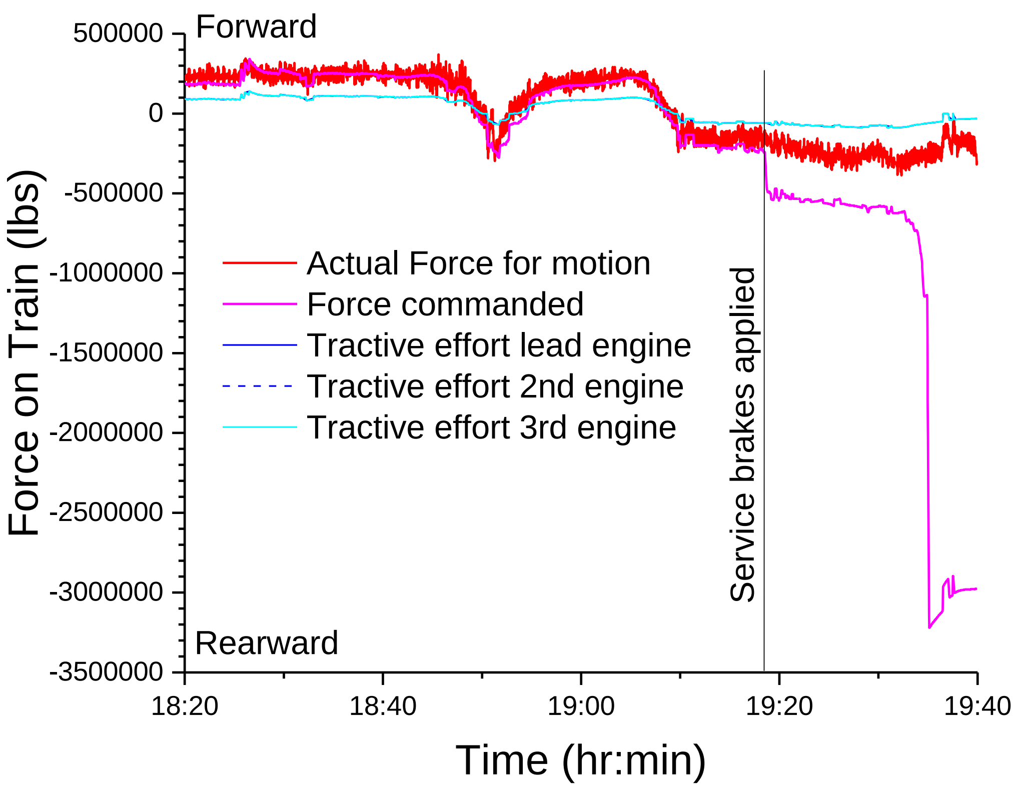

Figure 7 Actual and Commanded Force on Train

Coupler forces for every 10th element in the consist are plotted together with elevation verses miles in figure 8 and time in figure 9. Again, the CIDER/RailPlus module assumes working brakes so coupler forces are invalid after service brakes are applied at about 19:18:31. Note in figure 8 that all coupler forces transition from tension to compression when the last car goes over the hills.

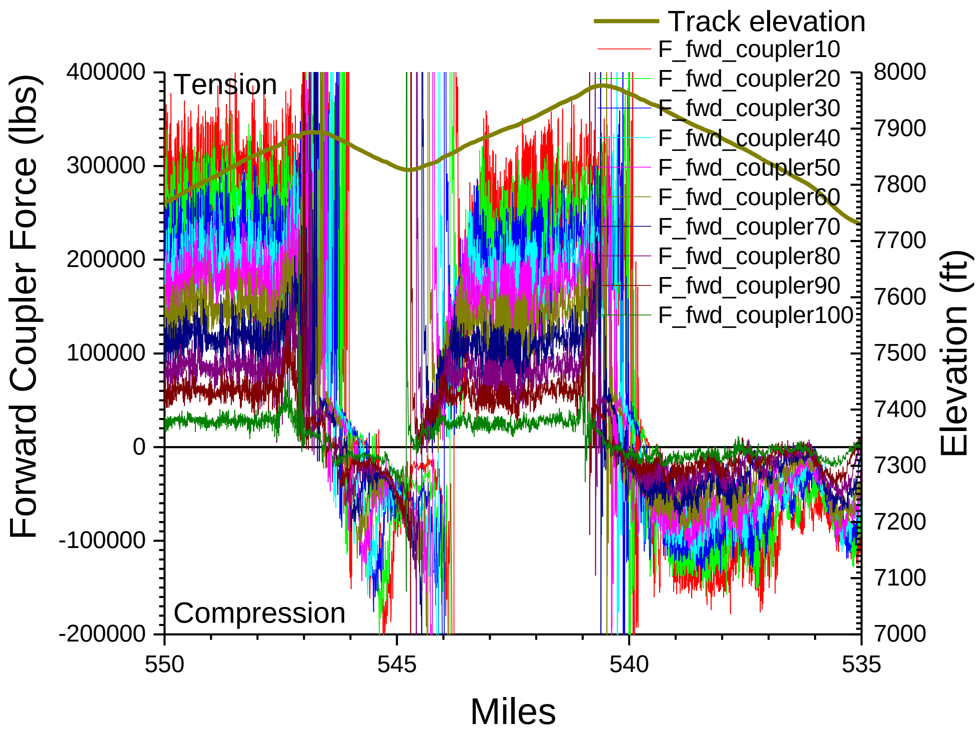

Figure 8 Coupler force vs mile

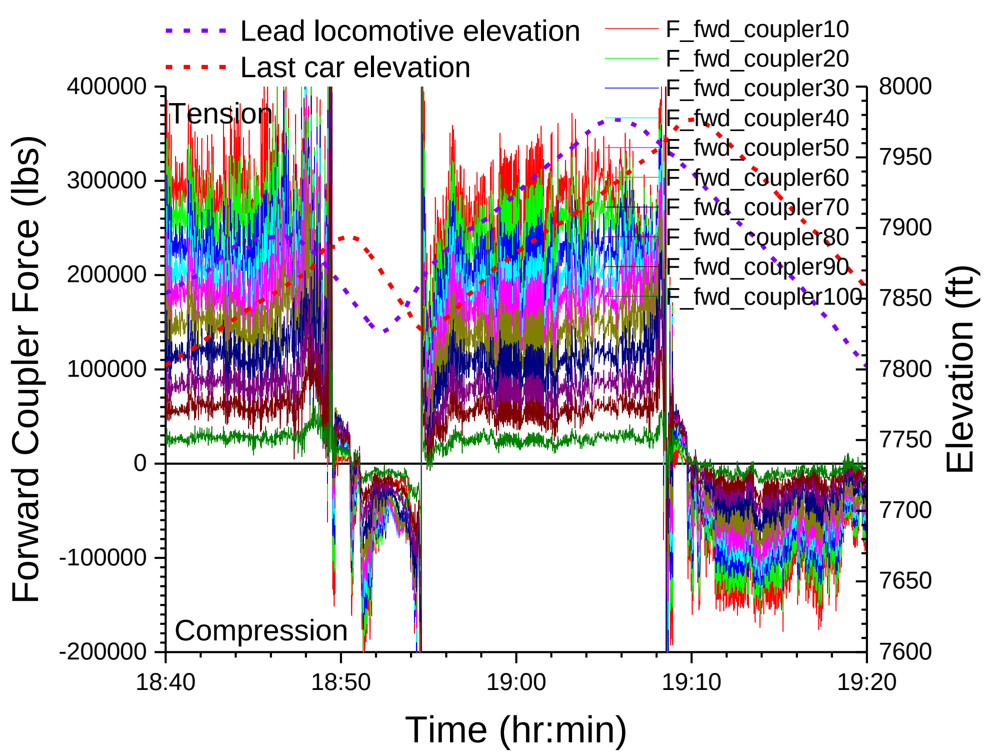

Figure 9 Coupler force vs. time

Couper forces are plotted with EAB and EOT brake pressure in figure 10. The two brake pressures begin to diverge soon after the train compresses on the downhill slopes. The resolution of the pressure data precludes a precise determination of the time the pressure divergence begins.

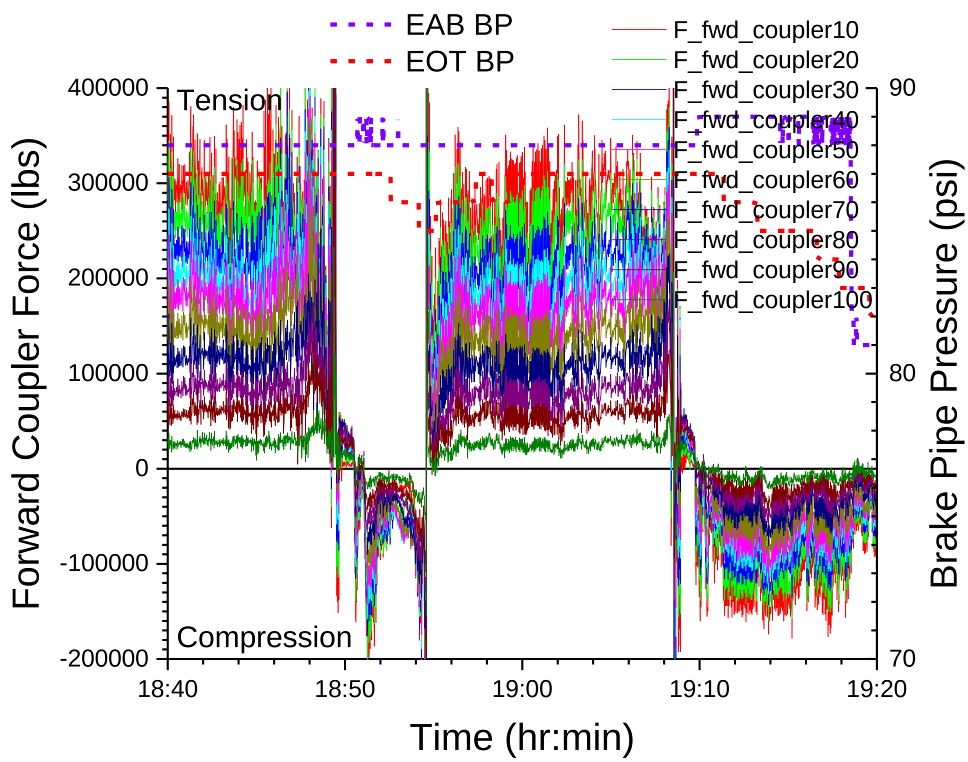

Figure 10 Brake pressure and coupler force

Airflow is plotted together with forward coupler forces for every 10th consist element in figure 11 and just for car 20[1] (element 23) in figure 12. Recorded airflow goes to zero[2] when coupler forces transition to compression and the distance between the cars shortens.

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[1] There was evidence of a kink in the air hose in front of car 20.

[2] By design, the airflow on the lead locomotive is not recorded below 20 CFM

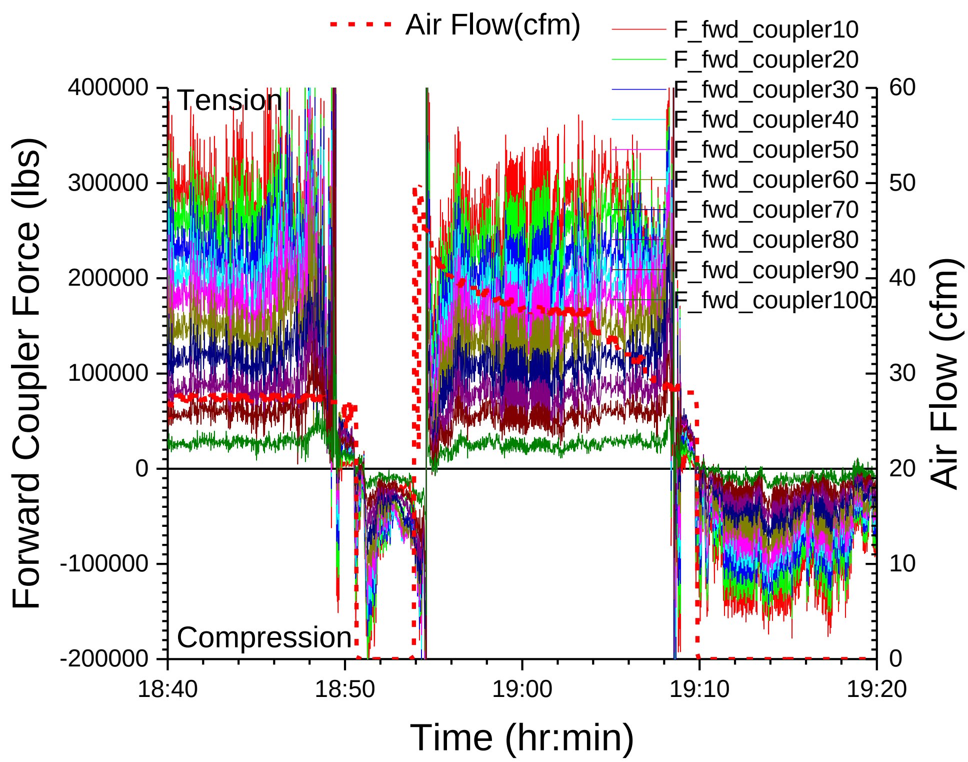

Figure 11 Airflow and coupler forces

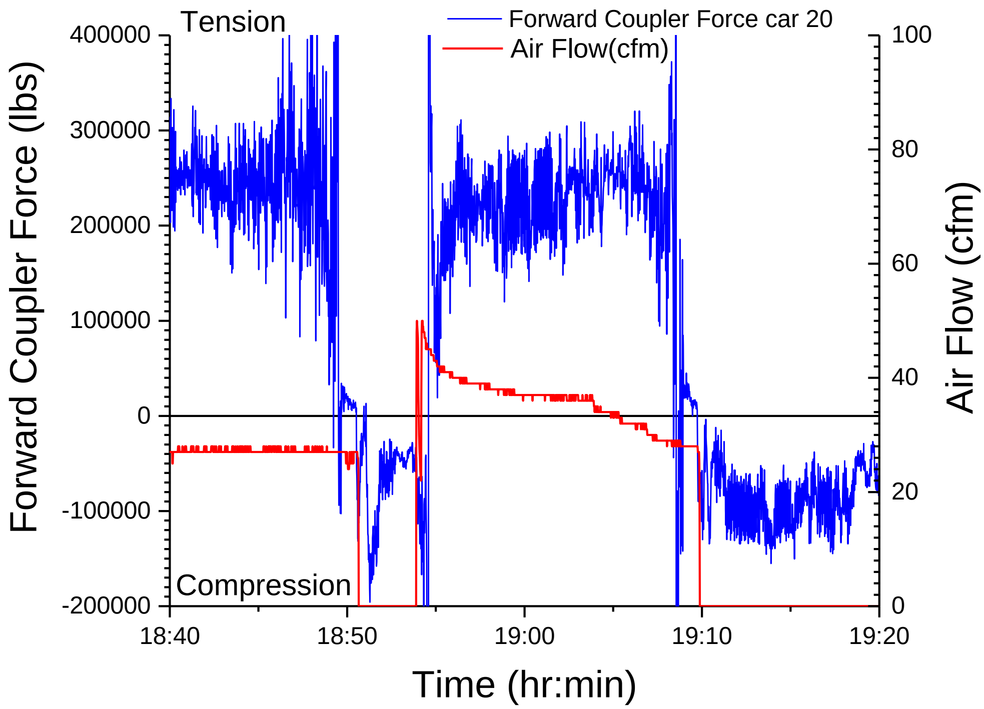

Figure 12 Airflow and forward coupler force on car

Summary

The application of service brakes about 19:18 produced little to no increase in deceleration force on the train and was well short of the deceleration force with normal brakes. Similarly, there was no increase in braking force when emergency brakes were applied about 19:36. Within the accuracy of the study (data and/or method) coupler forces changed from tension to compression and coupler length reduced at approximately the same time when the last car crest the two hill peaks. Recorded brake pipe airflow decreased to between zero and 20 CFM at these last car hill crest times.

Appendix A
Input Train Geometry


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    <Xlastwheel>62.08</Xlastwheel>
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  <Xlastwheel>82.54</Xlastwheel>
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  <Couplerfriction>150.0</Couplerfriction>
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    <Xlastwheel>73.13</Xlastwheel>
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    <Xlastwheel>44.29</Xlastwheel>
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    <Xlastwheel>29.33</Xlastwheel>
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    &lt;Xfirstwheel&gt;19.83&lt;/Xfirstwheel&gt;
    &lt;Xlastwheel&gt;25.67&lt;/Xlastwheel&gt;
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    &lt;AreaCd&gt;159.63&lt;/AreaCd&gt;
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    &lt;Couplerfriction&gt;150.0&lt;/Couplerfriction&gt;
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