NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC

February 8, 2018

Rail Derailment Motion Study

D.A. Crider

A. ACCIDENT: DCA17FR011

Accident Type:	Train Derailment
Location:	Hyndman, Pennsylvania
Date:	August 2, 2017
Time:	Approximately 5:01 AM
Trains:	CSX Q38831

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

This study determines the position and orientation time history of the train, in train forces, and the ratio of Lateral to Vertical force or L/V prior to the derailment.

Point of Derailment

The point of derailment (POD) was at 39.83536 degrees North latitude and 78.75034 degrees West longitude. This corresponds to an actual milepost of 193.82. For the purpose of this study, actual track miles will be used relative to this point. The first car to derail was the 35th car from the head of the train (The 40th element in the total consist 2092 ft. from the last locomotive).

Track Data

The track survey data is shown on a map in figure 1 with the POD noted. Elevation, associated derived pitch angle and cross level from the survey data are shown in figure 2, figure 3 and figure 4 respectively.

Figure 1 Track geometry with POD

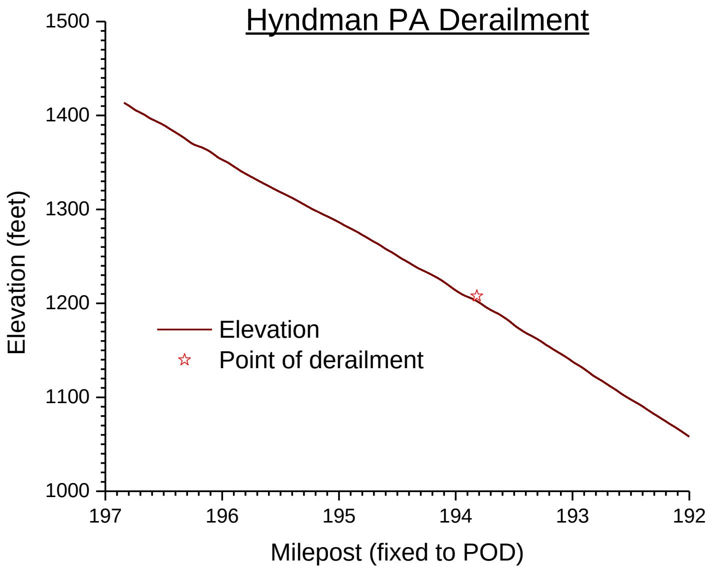

Figure 2 Track elevation

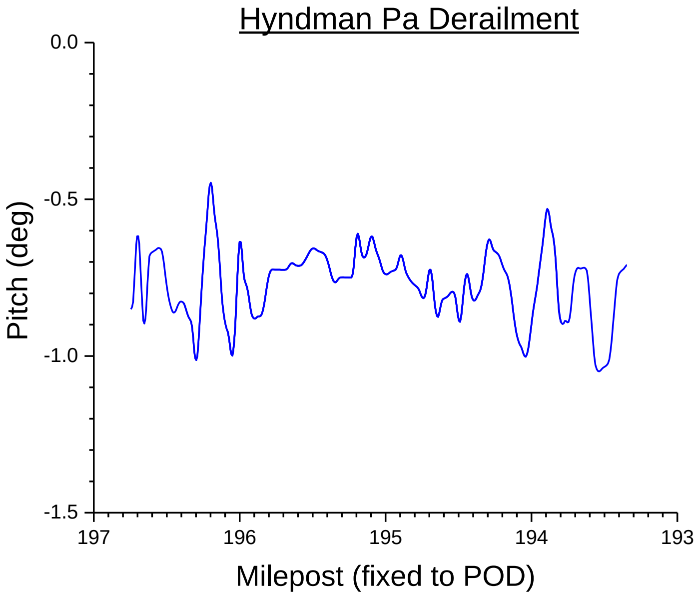

Figure 3 Pitch angle

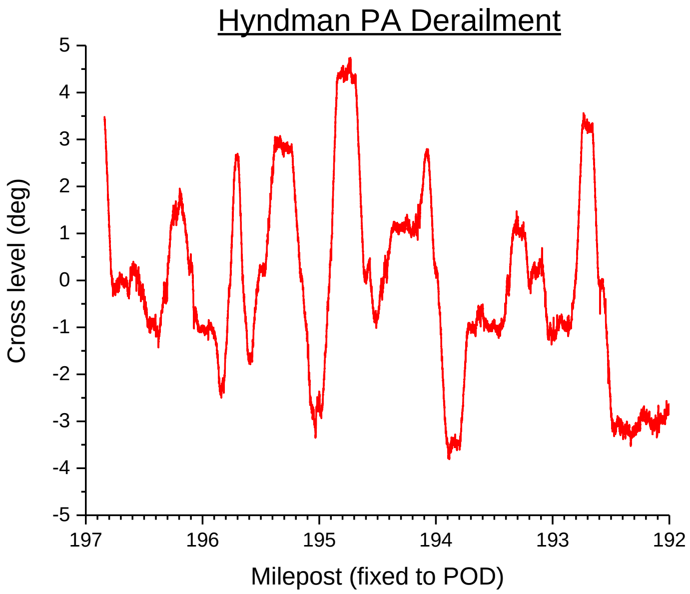

Figure 4 Track cross level

A close-up of the track position data shown in figure 5 shows that the track data has imperfections (noise). Accordingly, the track data was smoothed[1] as shown in the figure.

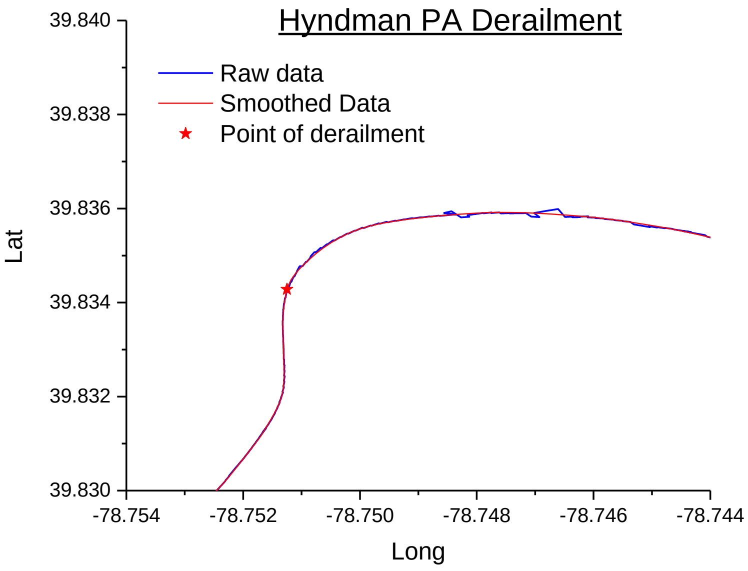

Figure 5 Track geometry smoothing

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[1] Track data was downsampled and then interpolated with an Akima spline to a 0.01 track mile interval.

With the data smoothed, track radius and curvature were derived and are presented in figures 6 and 7 respectively. Note that track curvature and radius are presented here relative to the decreasing milepost direction the train was moving on the track.

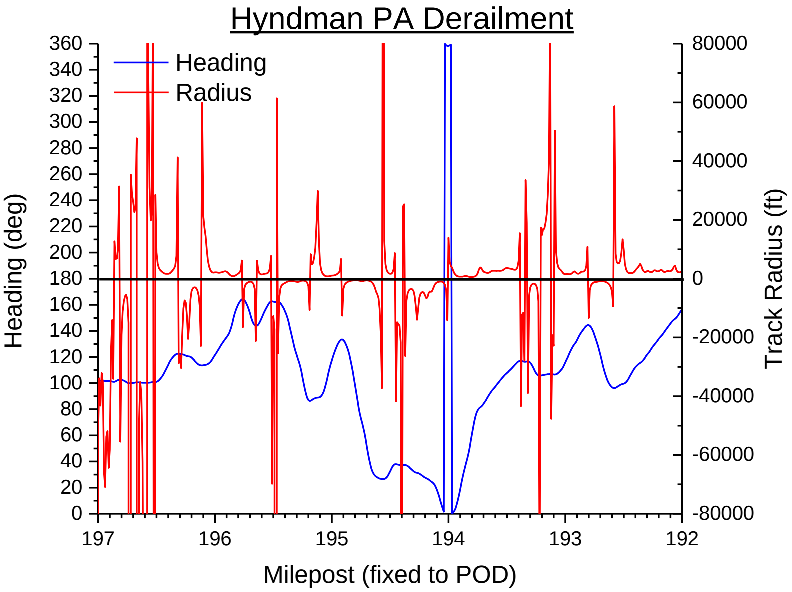

Figure 6 Track heading and horizontal radius

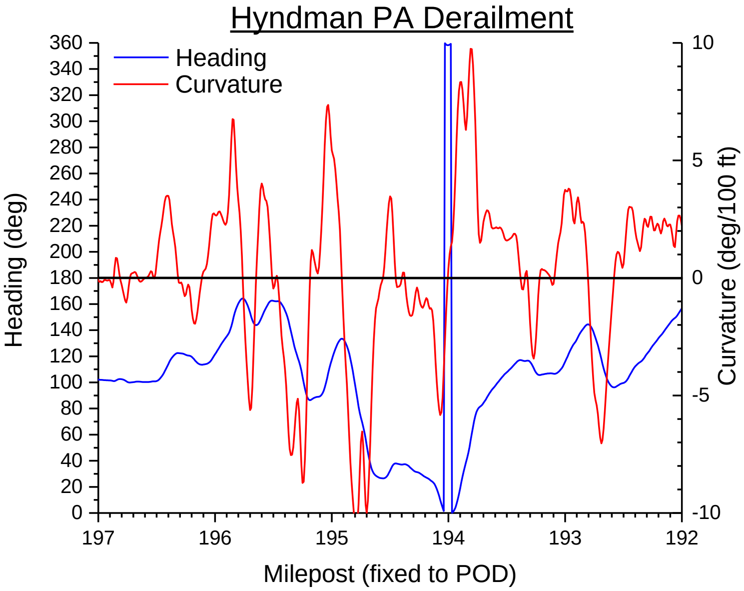

Figure 7 Track heading and curvature

Consist Data

The calculations requires 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 five locomotives on the head end. The first three locomotives were operating. The last two were not. The calculations require speed, tractive effort and brake pipe pressure as input. These recorded parameters are shown in figures 8, 9 and 10 respectively. In the case of speed, the data was smoothed for the calculations as shown to avoid false accelerations due to the 1 MPH recorded data resolution. The recorder also showed that the locomotives were in dynamic braking mode as the train went down the hill throughout the area of track approaching the POD where calculations were made. Accordingly, the “tractive effort” in figure 9 is dynamic braking force.

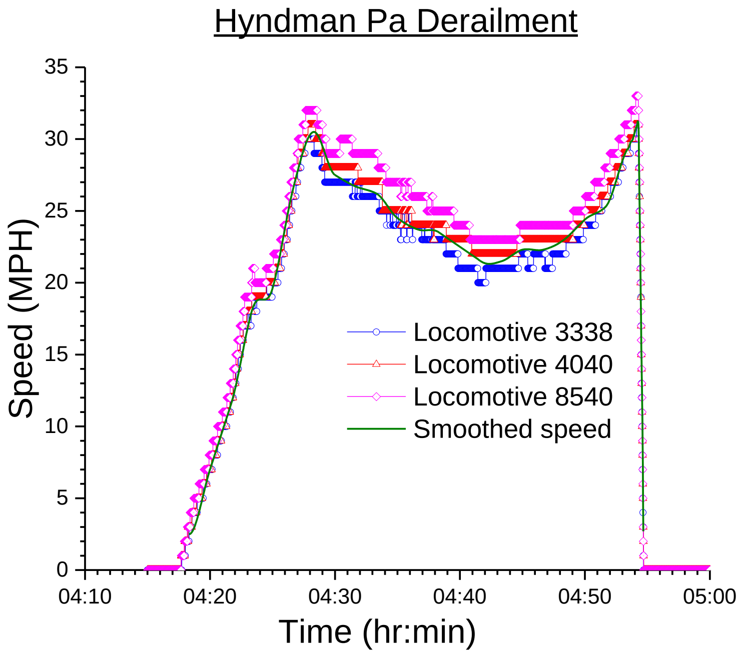

Figure 8 Speed

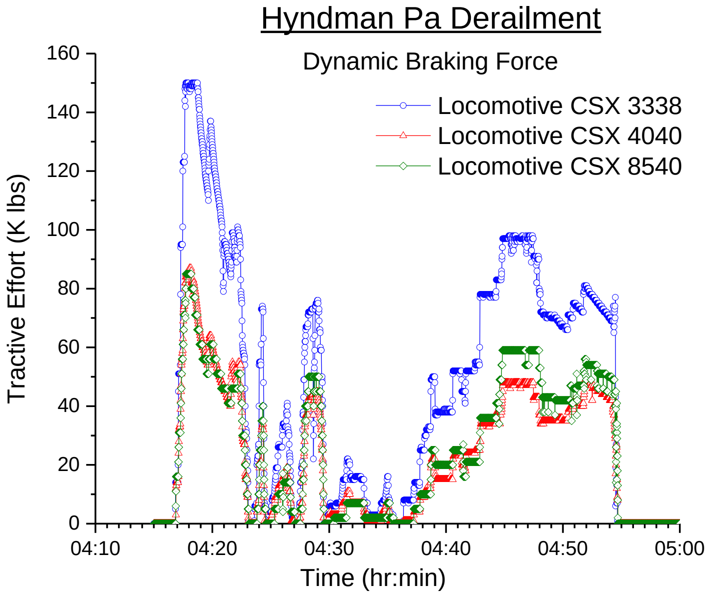

Figure 9 Tractive Effort (dynamic braking force)

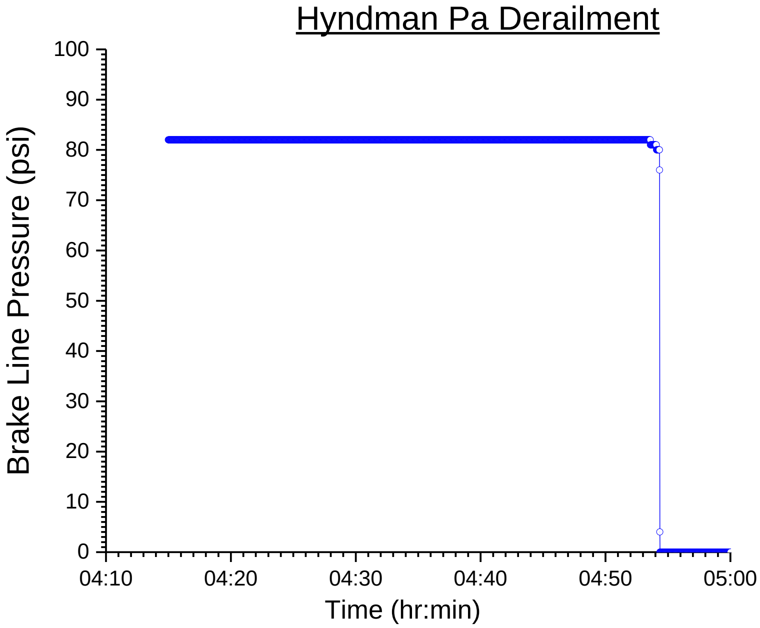

Figure 10 Brake pipe pressure

Motion Time History

The position time history shown in figure 11 was obtained with a reverse integration of the smoothed speed from the train's position at the last recorded speed shown in figure 8. This position was obtained by integrating the train's last position so that the high deceleration occurred at the point of derailment. Thus a milepost of 193.235 (39.8341, -78.7401) was used to begin the reverse integration.

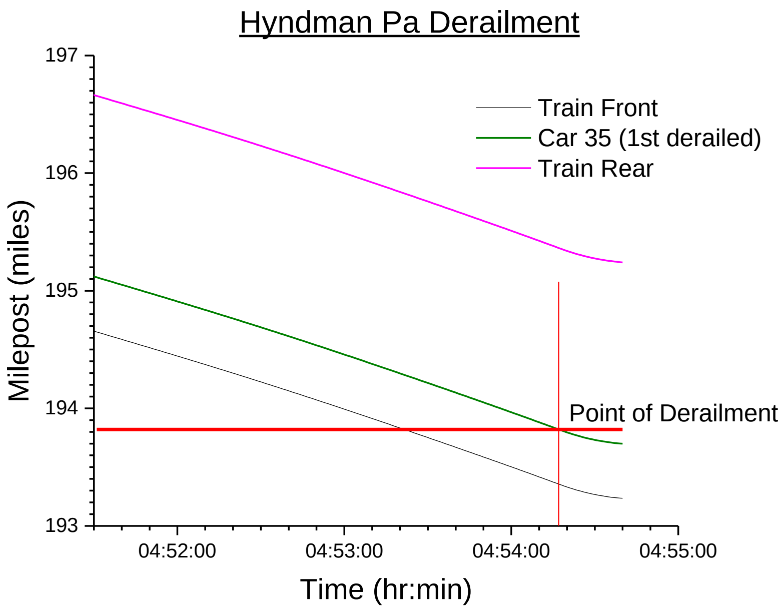

Figure 11 Position time history

Derailment Forces on Train

Handbrakes were applied on cars 34 through 64 (consist elements 39 through 69). Additionally the handbrake on car 10 (consist element 15) was partially on. The handbrake force was determined by assuming an even distribution of braking force among the hand braked cars, adding this force to the known dynamic and pneumatic brakes and iterating this braking force to match the force required for the motion. A hand braking force of 100 lbs. on car 10 and 500 lbs. on cars 34 through 64 was found to provide the match of force required as shown in figure 12. Note that at about 4:48, the braking force required for the train's recorded motion decreases while the force available calculating braking force from recorded brake pipe pressure and adding recorded dynamic brake forces remains constant. This is indicative of an increasing loss of braking effectiveness (brake fade).

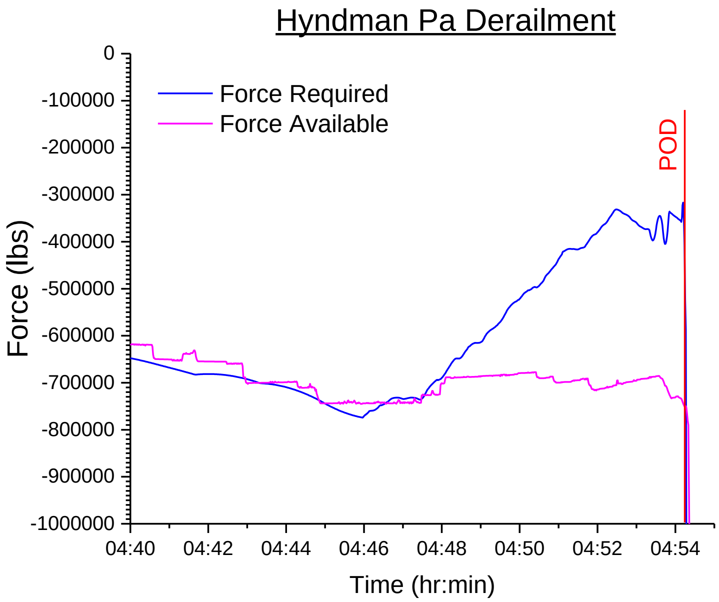

Figure 12 Force required for motion and force available.

Calculations were made using the force required for the recorded motion distributed between the cars based on recorded tractive effort and brake pipe pressure with normal brake behavior with handbrakes added to match the force required before the brake fade began. It is probable that the cars with handbrakes set would experience a greater brake fade than the other cars. Accordingly, to bracket the problem, calculations were made using the pre-fade braking distribution and with no additional braking from the hand braked cars.

The ratio of Lateral to Vertical force or L/V is an important contributor to derailment. Lateral force is due to a combination of the force required to produce the centripetal acceleration needed to move around turns and any left or right component of coupler force. The force required to produce the centripetal acceleration to move around a curve is proportional to lateral load factor N_y which is given in figure 13 for the first derailed 35^{th} car. Coupler force on the first derailed 35^{th} car is given in figure 14 for the pre-fade brake distribution and no braking from the hand braked cars condition. As can be seen in the figures, the 35^{th} car derailed with both the fore and aft couplers under compression. Since the local cars are in a right turn at the POD, the couplers are angled to the right. This results in an outward (left) force on the railcar which adds to the reactive centrifugal force balancing the centripetal force needed for the right turn.

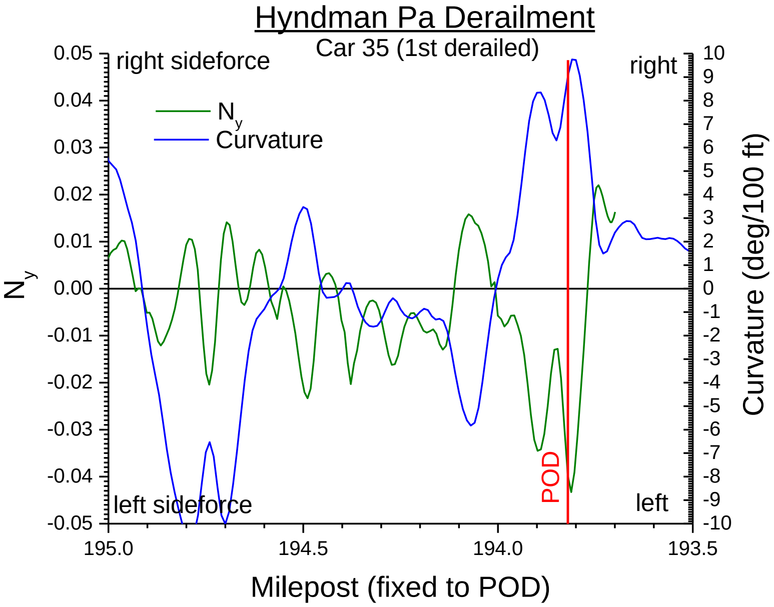

Figure 13 Lateral load factor

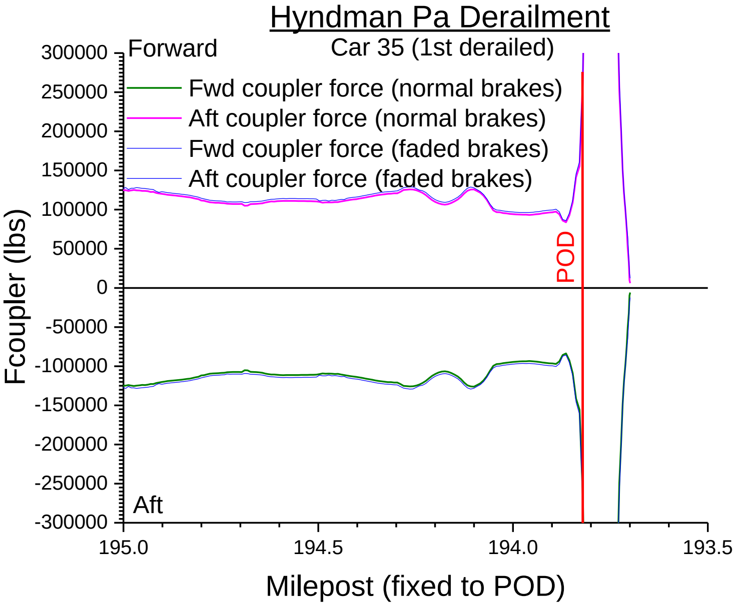

Figure 14 Coupler force on car 35

L/V is presented in figures 15 and 16 as a function of time and milepost respectively for the most critical (highest L/V) side for the pre-fade brake distribution and no braking from the hand braked cars case.

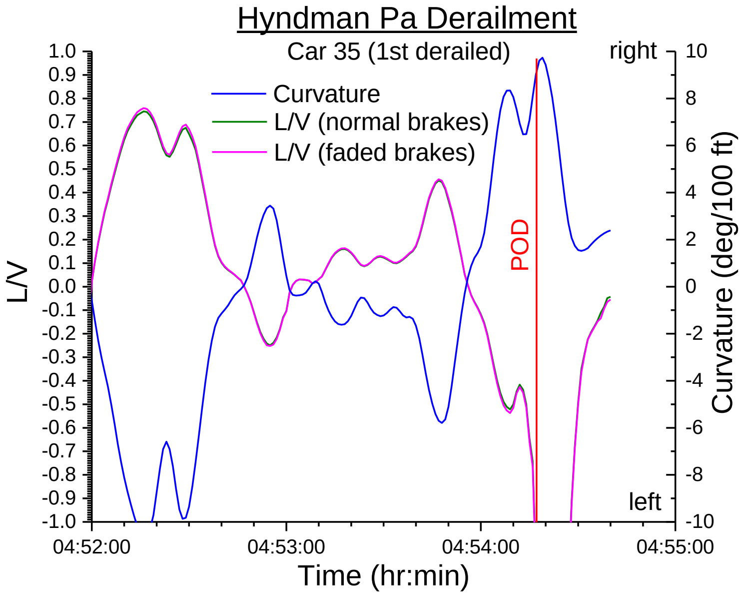

Figure 15 L/V vs. time

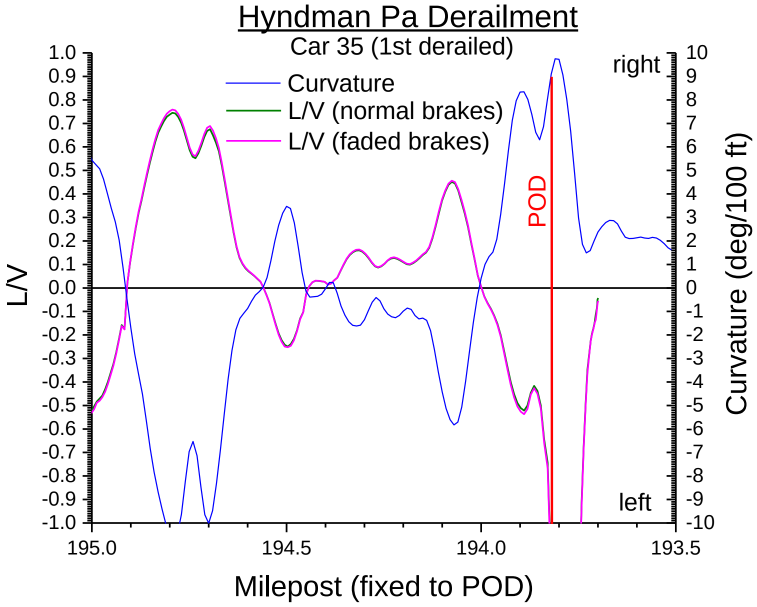

Figure 16 L/V vs. true milepost

After the train derailed L/V continued to increase due to the increase in in-train forces due to the deceleration of derailment. Thus the peak magnitude of L/V around the curve shown in figures 15 and 16 is well above what the peak value would have been had the curve been successfully negotiated. To help understand the magnitude of this difference, L/V was calculated with speed linearly extrapolated using the moderate train acceleration prior to the derailment rather than the recorded rapid deceleration to produce a “no derailment” case. The results are compared to the accident L/V in figure 17 for the normal brakes case.

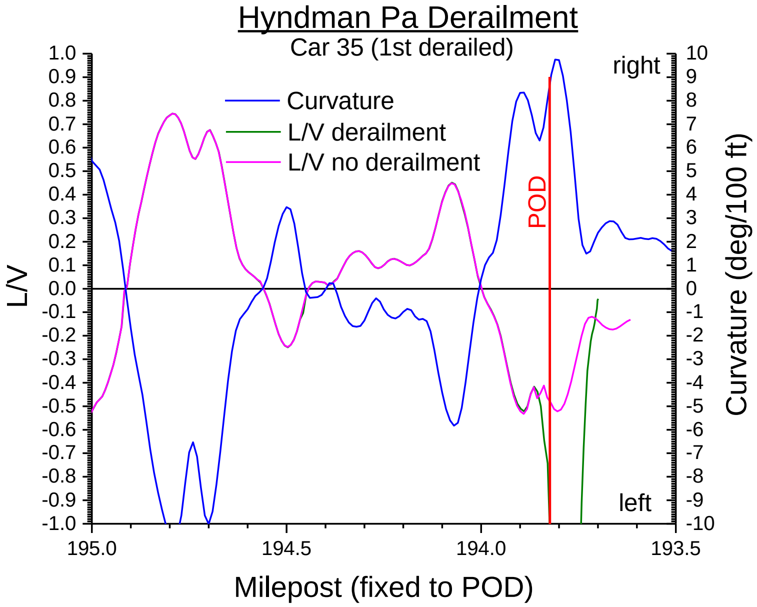

Figure 17 L/V "no derailment" comparison

Figures 16 and 17 show a high magnitude L/V at the POD. However, it was not as high as one would expect for a derailment with standard rail and wheels. Nor was it as high as the L/V experienced on the left turn at milepost 194.8 about two minutes earlier. However, the track group found that the rail head profile at the POD was significantly worn in a manner that would significantly reduce the L/V required for derailment. In addition, the mechanical group found significant built up tread and bluing due to heat which would also reduce the L/V required for derailment. Figure 12 shows rapid brake fade leading up to the time of the derailment. This rapid loss in brake effectiveness cooresponds to a significant increase in temperature during this period. One would expect some of the noted tread buildup to occur during this time. Accordingly it is likely that there was an increase in tread buildup between the left curve and the right POD curve 2 minutes latter.

Summary

The computer calculations showed that the train had experienced significant brake fade going down the hill and that L/V increased significantly at the point of derailment as the train went around a right curve. This should be considered together with the increased tread noted in the Mechanical Report and the worn rail head profile at the POD as both could lower the L/V required for derailment.

Appendix A
Input Train Geometry

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