NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

August 28, 2015

Locomotive Event Record and Diagnostic Systems

Specialist's Factual Report
By George Haralampopoulos

1. EVENT SUMMARY

Location:	Valhalla, New York
Date:	February 3, 2015
Operator:	MTA Metro-North Railroad
Train #:	659
Lead Car #:	4333
NTSB Number:	DCA15MR006

For a summary of the accident, refer to the *Crash Summary Report*, which is available in the docket for this investigation.

2. RECORDER GROUP

On February 3, 2015 a recorder group was established. The group convened on February 4, 2015 at the Metro-North Facility in North White Plains, New York.

Chairman:	George Haralampopoulos Aerospace Engineer National Transportation Safety Board
Member:	Bob Tomaszewski Railroad Safety Inspector Federal Railroad Administration
Member:	Michael Yarmarkov, Sr. Electrical Engineer Equipment Engineering, Maintenance of Equipment MTA Metro-North Railroad
Member:	Christopher Taft, General Road Foreman Transportation Department MTA Metro-North Railroad

3. FEDERAL EVENT RECORDER CARRIAGE REQUIREMENTS

Federal Regulations regarding the carriage requirements of event recorders on railroad locomotives can be found in Federal Railroad Administration 49 *Code of Federal*

Regulations (CFR) Part 229.135. The locomotive was operating such that it was required to have a crash survivable event recorder recording a minimum of 25 parameters depending upon the specific type and configuration of the locomotive type as described in 49 CFR Part 229.135(b)(3).

4. DETAILS OF RECORDER INVESTIGATION

Train 659 consisted of 8 cars forming four two-car pairs. Table 1 shows the car numbers for each car in train 659. Each pair consists of a rear 'A' car and lead 'B' car. A Federal Railroad Administration (FRA) compliant, Bach-Simpson event recorder, existed in the 'A' car of each pair.

Additionally, each pair contained two central diagnostic systems (CDS), with one CDS installed per car. The CDS contained additional event data not recorded by the FRA required recorder.

Table 1. Train 659 Car Number from Lead to Rear.

Pair	Car Number (B-A)
1	4333-4332
2	4197-4196
3	4175-4174
4	4309-4308

The event recorder from the lead pair, 4333-4332, was removed and placed in a surrogate car for download (figure 1). The event recorder was successfully downloaded with oversight by the NTSB.

Figure 1. The lead car event recorder connected to the surrogate car.

Seven of the eight CDS event logs were successfully downloaded on February 5, 2015 (figure 2). Due to severe thermal damage, a download of the car 4333's CDS was not possible. Car 4332's CDS was downloaded by applying external power to the CDS circuit breaker in order to avoid power application to the damaged 4333 B-Car.

Figure 2. CDS location of car 4309.

4.1. Event Recorder Data Description

The data from lead pair 4333-4332's event recorder contained 85 parameters and contained about 18 days of data from January 17, 2015 to February 4, 2015. The event trip was identified based on the parameters recorded. [1,2]

When the car acts as the front of the train, the Horn, and Cab Signal parameters are available on the event recorder. Conversely, the Horn and Cab Signal parameters are not available to an event recorder of a car acting as the rear or middle of the train consist; therefore, data from the trailing car pairs were considered redundant and only data from the lead pair event recorder is included in this report. [3]

4.1.1 Derivation of Event Recorder Speed and Distance

The locomotive's speed is derived within the event recorder by the event recorder's software.

A wheel size is manually entered into the event recorder's software to correct the calculated speed. Using a wheel size of 34.6 inches for the lead pair event recorder, as

[1] Henceforth referred to as the lead pair for the duration of this report.
[2] Thirty of the 85 parameters on the event recorder were spare or undefined.
[3] Rear and Front are defined by the train's direction of travel.

measured by investigators, the speed values are computed automatically by the software.

The event recorder provided parameter, distance travelled, did not permit the parameter to be extracted; therefore the locomotive's distance traveled was calculated by the parameters, speed and time, recorded by the event recorder using the following formula:

$$(1)\ D = d_0 + \frac{v\ (t_1 - t_0)}{3600}$$

Where:

D = Distance Traveled (miles)

d_0 = Prior Distance (miles)

v = Velocity (mph)

t_1 = Time (sec)

t_0 = Prior Time (sec)

The derived parameter is referred to as Calculated Distance Feet and Calculated Distance Miles in this report. The distance was only calculated for the period of data provided in this report and began incrementing from a value of zero with a corresponding speed of zero.

4.2. CDS Data Description

The CDS records an event log from parameters available on its network. Its network is composed of 10 different systems:

- Auxiliary Power System (APS)
- Door Control System Left 1 (DCSL1)
- Door Control System Left 2 (DCSL2)
- Door Control System Right 1 (DCSR1)
- Door Control System Right 2 (DCSR2)
- Heating Ventilation Air Condition (HVAC)
- Logic Control Unit (LCU)
- Propulsion Control Unit B (PCUB)[4]
- Propulsion Control Unit F (PCUF)[4]
- Automatic Train Control (ATC)[5]

The event log consists of 100 parameters recorded at a variable rate based on the system's configuration. Each CDS records information specific to its respective car;

[4] The front of a single car is considered the 'F' end, the rear of a single car is the 'B' end
[5] Only a CDS downloaded from the 'B' car contained input from the ATC.

however, a few parameters such as P-wire, are train line parameters and are recorded to each CDS within the train consist.

The data obtained by each CDS spanned about 2 days from February 2, 2015, to the date of download on February 5, 2015. The event trip was identified by the CDS recorded GPS date and time parameters.

4.1.2 Derivation of CDS Speed

The CDS uses the wheel speed signal from PCUB and already corrected for actual wheel diameter using the GPS system. No post processing was performed on the CDS data and all CDS speed values are reported as is.

4.3. Time Correlation

Correlation of the event recorder and each CDS' respective time to local eastern standard time (EST) was established by:

- Aligning each individual CDS to obtain a common GPS time.
- Using a common parameter between the CDS and Event Recorder.
- Finding common events between the CDS and external third rail power station recorded data. [6]

4.3.1. Time Correlation between CDS

The CDS is synched to a GPS source and corrects to local time automatically. Minor offsets were noticed between each CDS event log. Correlation of the seven CDS event logs was established by aligning the commonly recorded P-wire Current parameter. Car 4308's recorded P-Wire Current parameter was used as the datum. The offset of each CDS is shown in Table 2.

Table 2. Offset between each CDS with car 4308 used as a datum.

Car	Offset (additional seconds)
4332	0.4
4197	0.2
4196	0.8
4175	2.8
4174	1.8
4309	0.2

[6] Refer to the "Track & Power Group Chairman" Factual Report for more information regarding the third rail and power station.

4.3.2. Time Correlation between the Event Recorder and CDS

The event recorder contains an internal clock that is adjustable at the time of download or given as elapsed seconds recorded. The data was exported in elapsed seconds recorded (ESR) and correlated to the CDS using the P-Wire parameter common to both recorders. The following relationship was formed:

CDS = ESR + 63286.5 seconds

4.3.3. Adjusting for Errors in Correlated Time

Errors in the CDS's GPS clock were adjusted by aligning the CDS recorded third rail voltage parameter with the IRIG time supplied by the power station's event log.[7]

The power station recorded a status message at 18:26:17.2 EST, consistent with activity from the CDS recorded third rail voltage parameter at 18:26:15. Therefore, an additional 2.2 seconds were added to the overall CDS and event recorder time.

4.4. Parameters Provided and Verified.

Table 3 and 4 lists the parameters from the CDS and event recorder, respectively, that were verified and provided in this report. Additionally, table 5 contains the unit and discrete state abbreviations for the verified parameters. [8]

Table 3. Verified and provided CDS parameters.

Parameter Name	Parameter Description
1. CAR#_Deceleration[a] (mph/sec)	Longitudinal Deceleration
2. CAR#_P-wire Current [a] (mAmp)	Train P-wire Current
3. CAR#_Speed [a] (mph)	Speed
4. CAR#_Third Rail Voltage (Vdc)	Third Rail Voltage

Table 4. Verified and provided event recorder parameters.

Parameter Name	Parameter Description
5. Cab Sig Ack A/B-Car (discrete)	Cab Signal Acknowledge A/B Car
6. Cab Signal (discrete)	Cab Signal Code
7. Brake Cylinder A/B-Car (psi)	Brake Cylinder Pressure A/B Car
8. ER Speed (mph)	Event Recorder Speed
9. Brake Pipe Pressure (psi)	Brake Pipe Pressure
10. Emer Brk Trainline (discrete)	Emergency Brake Trainline
11. Horn A/B-Car (discrete)	Horn A/B-Car
12. Train P-Wire (mAmp)	Event Recorder Train P-wire Current
13. HLB A/B Car[b] (discrete)	Headlight Bright A/B Car

[7] IRIG is a standard for transferring precise time information synched by atomic clocks.
[8] A discrete is typically a 1-bit parameter that is either a 0 state or a 1 state where each state is uniquely defined for each parameter.

Parameter Name	Parameter Description
14. Calculated Distance Feet[b] (ft)	Calculated Distance Travelled
15. Calculated Distance Miles[b] (m)	Calculated Distance Travelled

Table 5. Unit and discrete state abbreviations.

Unit and Discrete State Abbreviations	Description
NC	no cab code
75	cab signal '75'
120	cab signal '120'
180	cab signal '180'
270	cab signal '270' (not used)
420	cab signal '420' (not used)
On	active
Off	not active
psi	pounds per square inch
mAmp	milli-amperage
mph	miles per hour
m	miles
mph/sec	miles per hour per seconds
Vdc	voltage direct current

Note: [a] CAR# refers to the respective CDS car number.
[b] Parameter is not plotted but provided in the tabular data as an attachment to this report.

5. PLOTS AND CORRESPONDING TABULAR DATA

The following three figures contain data plotted from the lead pair event recorder and CDS event logs during the event on February 3, 2015.

Figures 1 is an overview of the entire event trip of train 659. Figure 2 is a two minute segment from figure 1, highlighting the third rail voltage spike.

Figure 3 contains third rail voltages from all seven CDS event logs and highlights the sequence of events following the third rail voltage spike.

The data indicated that the train departed from Grand Central Terminal at 17:46:28 EST. Recorded parameters related to the engineer's activity including: horn application, cab signal acknowledgement, and throttle movements (P-Wire), were active throughout the trip.

The trip remained uneventful until 18:26:10 EST with the changes to the following recorded parameters: the P-wire was reduced to 0 mAmps, Brake Pipe Pressure dropped to 0 psi, and Brake Cylinder Pressure from car 4333-4332 increased to about 50 psi. These changes were consistent with the engineer placing the train into emergency braking.

Prior to the emergency braking, a series of horn applications were recorded at 18:25:56, 18:26:02, and 18:26:07 EST.

The train's recorded speed during the emergency application was 59 mph and decreased to 51 mph when the CDS decelerometer recorded an increase in deceleration at 18:26:13 EST from 2.1 to 3.5 mph/sec, consistent with impact. The last horn activation was from the start of emergency braking at a calculated distance of about 230 feet from the recorded spike in the decelerometer.

The train continued to decelerate through 40 mph when at 18:26:17 EST, about 250 feet forward on the recorded spike in the decelerometer, the CDS recorded third rail voltage parameters experienced a sequence of events consistent with the damage of the third rail. The recorded data was compared to the recorded events from the SCADA system by the nearby power station and the drop in CDS recorded third rail voltages were consistent with the events captured by the SCADA system.[9]

The tabular data used to generate figures 3 through 5 is provided in electronic comma separated value (*.csv) format as attachment 1 to this report.

[9] Refer to the "Track & Power Group Chairman" Factual Report for more information regarding the SCADA event log.

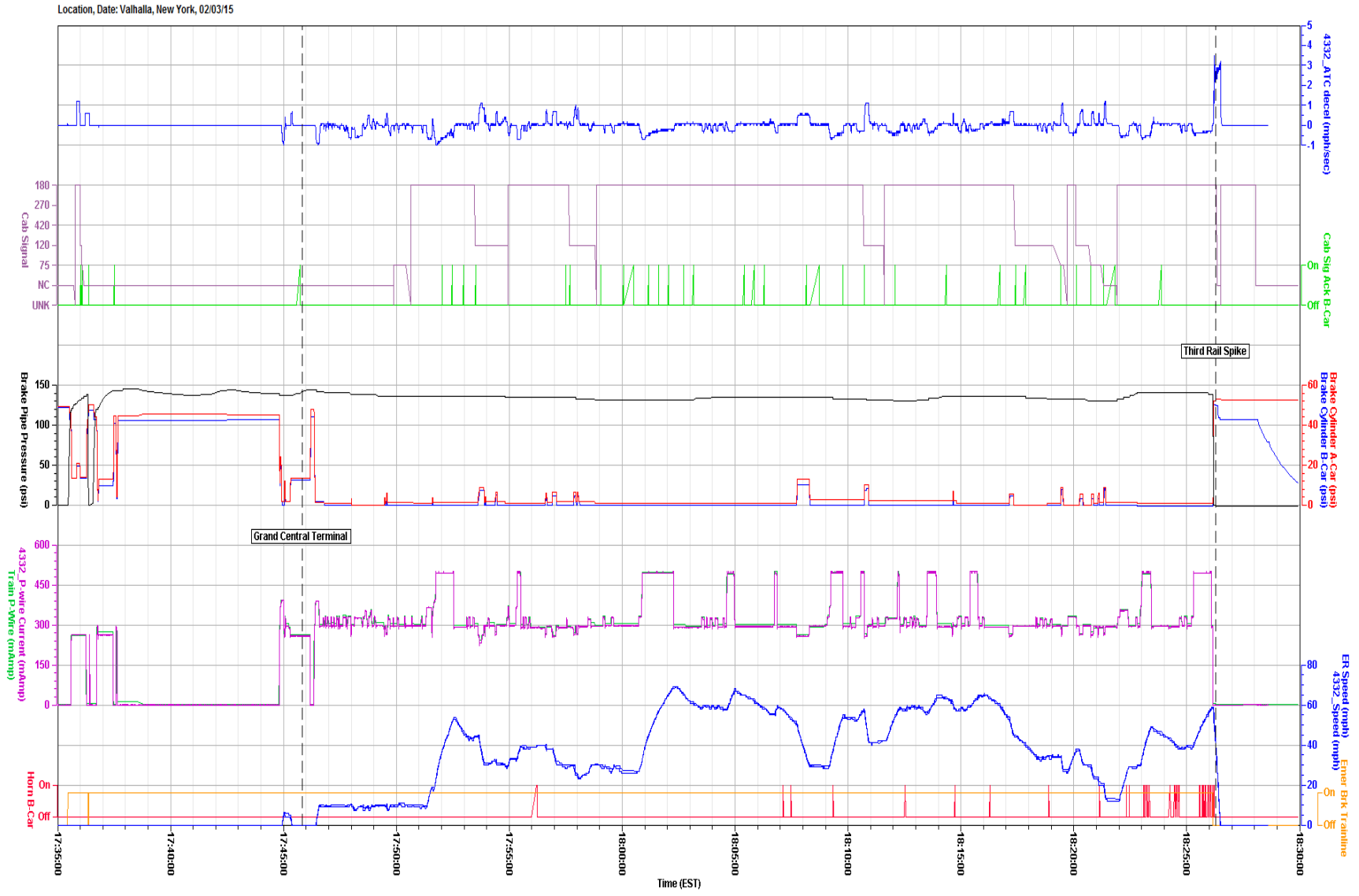

Figure 3. Plot of event recorder parameters for entire event trip.

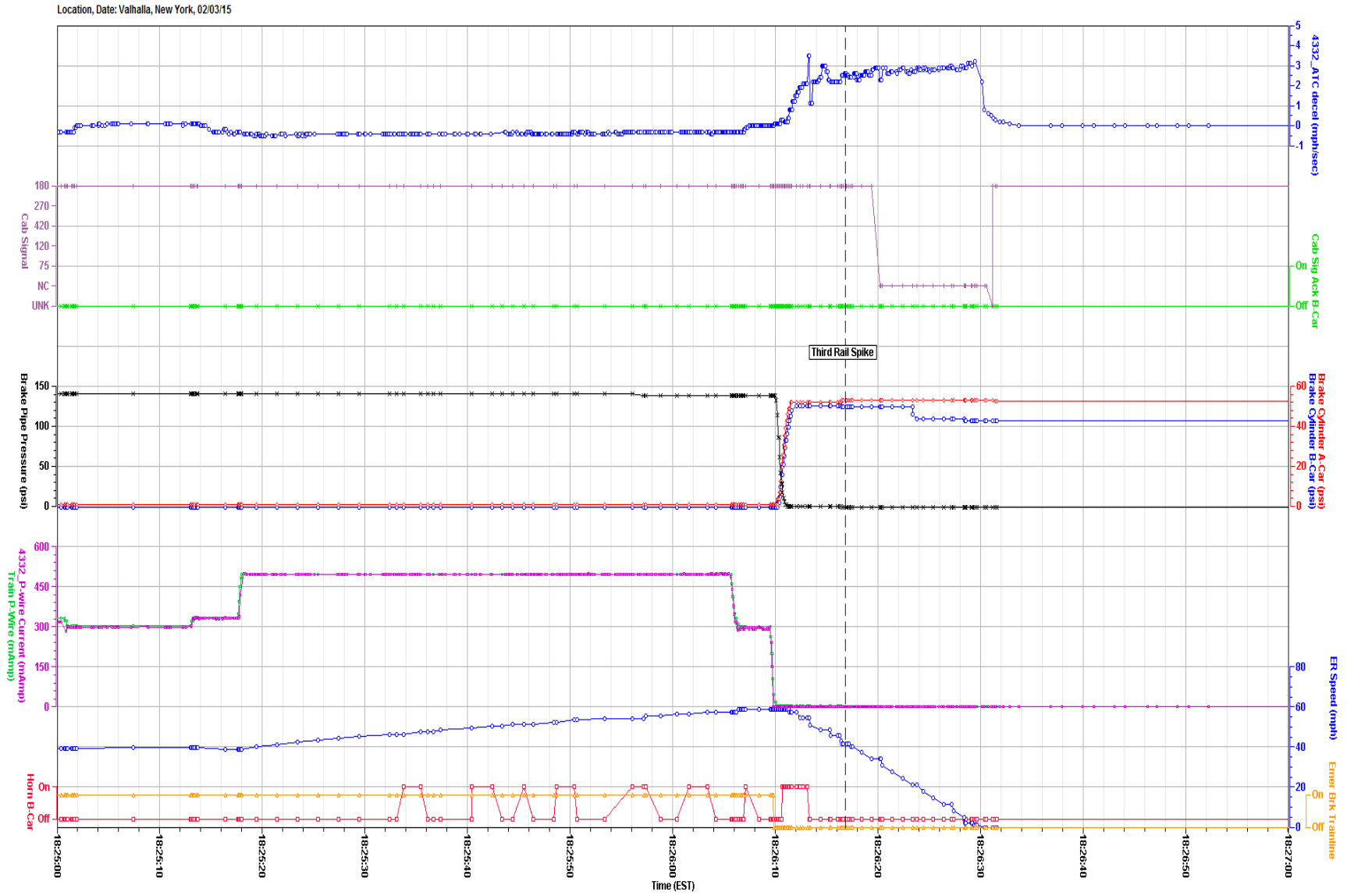

Figure 4. Plot highlighting emergency brake application.

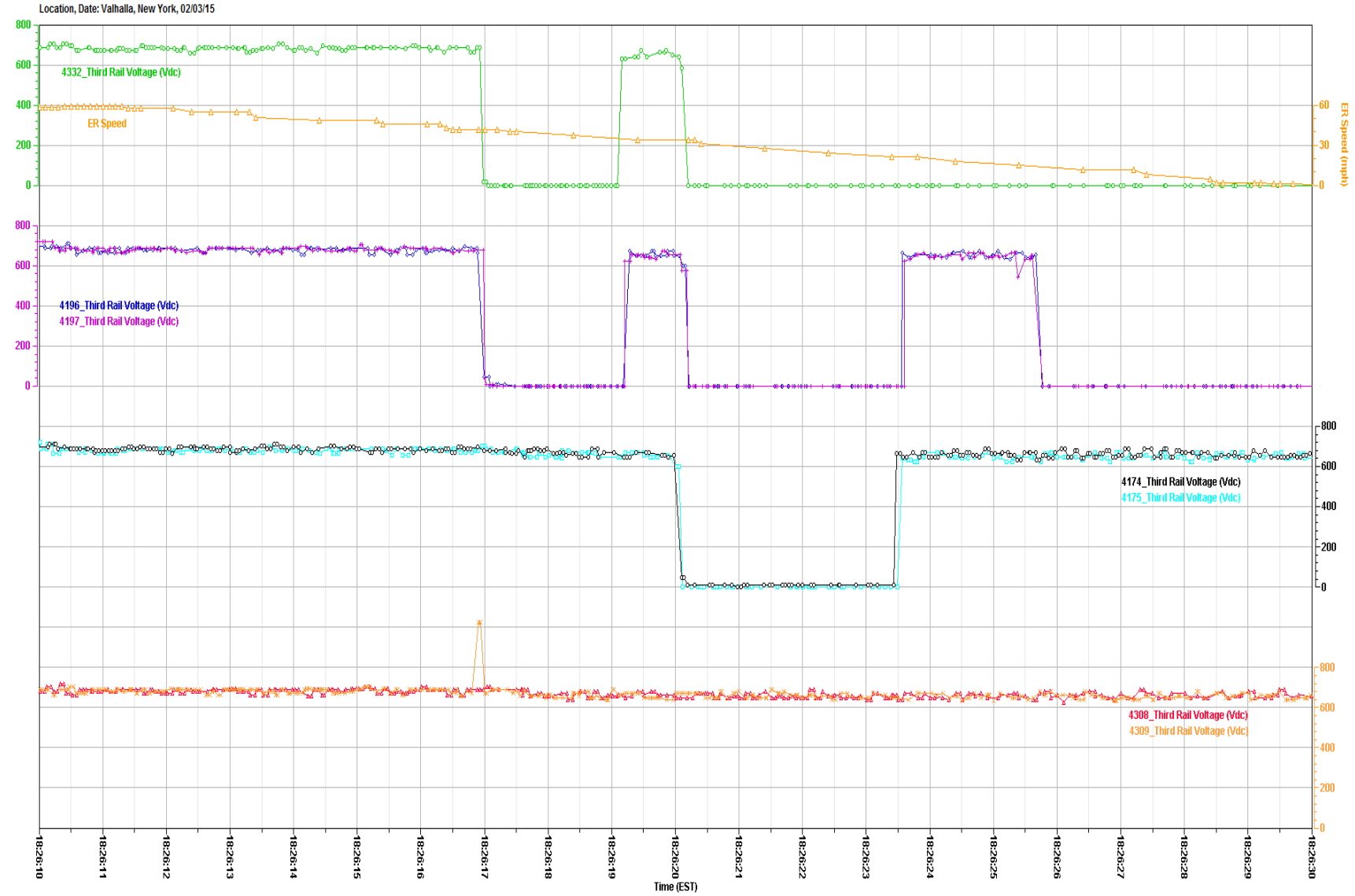

Figure 5. Plot of CDS third rail voltage sequence of events.