M E M O R A N D U M

Washington Metropolitan Area Transit Authority

SUBJECT: Mitigations Supporting Final Return to Service Plan

DATE: October 13, 2022

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This memo explains the reasoning behind the mitigations that support the final Return to Service Plan.

<u>Metro believes a program of ongoing inspections, including back-to-back measurements, are the best mitigation for wheel migration absent a root cause identified by the NTSB investigation.</u>

To substantiate this proposal, Metro has reviewed a significant amount of data in three distinct categories:

1. Successful operation in passenger service for 10.5 million miles prior to first reported back-to-back failure in 2017.

2. Targeted testing in simulated service with AW2 load weight (26,250 lbs, simulating 175 passengers/car) and 81,824 accumulated miles on all lines in November 2021 for 15 consecutive days with no reported failures and additional testing in simulated service with AW0 load weight (empty car) on all lines between June 13 to June 30 with no reported failures. Both tests were done with low and high tonnage cars.

3. RTS data since June 2022 – Successful operation in passenger service for over 2 million miles over 120 days since June 16, 2022

Metro also continues to use vehicle/track interaction data, track geometry vehicle data, track walking inspections and monthly interlocking inspections to confirm track conditions are safe for operations for all fleets.

Service on Blue, Orange, Silver

As stated in the Return to Service Plan, Metro will run on any line, including the Blue, Orange, and Silver lines.

To assess the risk of operating on the additional three lines, The Office of Maintenance of Way – Track Engineering (MOWE-TE) considered the differences between the Red, Green, and Yellow lines versus the Blue, Orange, and Silver lines (Table 1). MOWE-TE found that many track characteristics matched.

The main difference between Red, Green, Yellow and Blue, Orange, Silver is two curves with a tighter-than-average radius. between Metro Center and McPherson Square. These curves, between Metro Center and McPherson Square, have restraining rail and are operated at a designed speed of 35 mph.

Table 1. Comparison of Track Characteristics by Line

Characteristic	Red, Green, Yellow	Blue, Orange, Silver
# of turnouts	170	152 (184 with Silver Line Phase II extension)
# of restraining rails	4	4
Minimum curve radius	755 ft	700 ft
# of interlockings	39	38 (46 with Silver Line Phase II extension)
Curve geometry	In line with Design Criteria	In line with Design Criteria
Operating speed	59 mph*	59 mph
ROCC management	G/Y requires two Ops desks	BOS requires two Ops desks

*Operating speed between Georgia Ave-Petworth and Greenbelt, and between Anacostia and Branch Ave is 65 mph

Full Fleet Eligible for Revenue Service

As stated in the Return to Service Plan, Metro will run the full fleet. Metro will not run cars with axles that failed baseline measurements.

Office of Vehicle Programs (CENV), Office of Track and Structures (TRST), and MOWE-TE considered general elements that could cause wheel migration: press tonnage; interference fit and surface finish, wheel climb and restraining rail; and frog and interlocking conditions. Metro does not propose that any of these elements, in isolation, are the root cause of the October 12, 2021 derailment.

Interference Fit and Surface Finish

In 2014, several legacy cars were identified as having wheel migration. A fleet inspection was performed, and 30 cars were identified with wheelsets that exceeded the back-to-back tolerance. LTK Engineering was contracted to investigate the occurrences and identify the root cause. LTK Report 041 (2015) identified three deficiencies in Metro’s wheel assembly process that contributed to wheel migration at that time: (1) Use of a non-standard skive finish on the wheel bore, (2) Insufficient press-fit Interference, and (3) axle hardness variation. The report also found that Metro lacked formal standards and processes.

Metro responded by establishing standards and implementing improved wheelset assembly procedures, and a new Maintenance Service Instruction (MSI) was approved. The MSI dictated that only non-texture hub finishes should be used and established requirements for interference fit and axle hardness. To compensate for the axle hardness variation (5000-series railcars), the press tonnage was increased to 65-95 tons. Failed wheelsets and components were removed from service, and the legacy cars wheelsets were rebuilt to the revised tonnage range as a part of their scheduled truck overhaul programs.

Initially, the 7000-series wheelsets were manufactured by ORX using the former WMATA press tonnage specification of 55-80 tons. The press tonnage requirement was subsequently increased to 65-95 tons in July 2017, which was consistent with the legacy fleet requirement.

Wheelset Press Tonnage

Wheelsets built prior to 2017 do not pose an unacceptable risk of wheel migration because the process and material conditions identified in the LTK-041 report are not present in the ORX built wheelsets. The wheel hubs were machined with Association of American Railroads (AAR)-compliant finish.

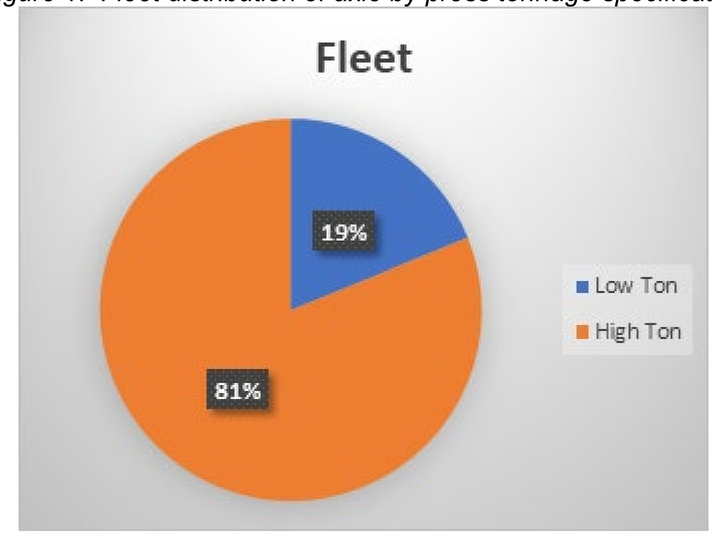
Also, Metro performed an endurance test under ETR 140107, running two 8-car trains for 800 miles per line at AW2 load weight (26,250 lbs, simulating 175 passengers/car). The test was successfully completed after 15 days of simulated revenue service operation, with no back-to-back measurements exceeding tolerance.

Furthermore, as stated, Metro will continue its frequent wheelset inspection program, verifying the back-to-back dimension under MSI 140026 on a seven-day interval for each car in passenger service. The inspection tools can reliably identify back-to-back changes of .005” on average.

Failed axles analysis

The total population of axles on the 7K fleet is 2,992. Of this population, 564 axles were originally assembled with at least one wheel satisfying the lower press tonnage specification; 2,428 were assembled with the higher press tonnage specification, representing 19% and 81% of the fleet respectively as shown in Figure 1 below.

Figure 1. Fleet distribution of axle by press tonnage specification



Metro has reviewed the press records for axles on the 7K fleet and evaluated the failures based on the press tonnage criteria. The total count of failed axles is 57, which is from historical failures and those found in October 2021 via a measurement "blitz". In May 2022, the third revision of the MSI 140026 went into effect, which mandated the use of an improved, more precise measuring tool and establishing a more stringent criterium. Specifically, that back-to-back measurements that equaled the upper limit of 53 3/8 inches were now considered a failure. This resulted in the identification of 22 additional failures, for a total of 79.

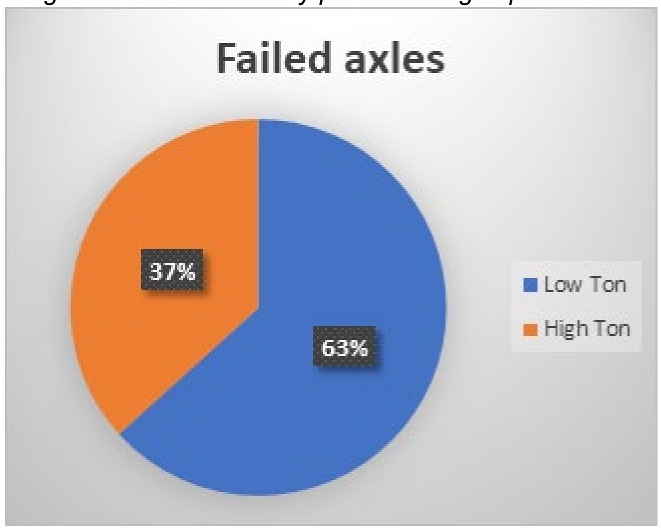
A summary of axle data is provided in Table 2 below.

Table 2. Summary of Axle Failures by Press Tonnage

	Number	Percent
Total # axles	2,992	
# of failed axles	79	2.6%
# of failed axles with Press Tonnage above 65 tons	29	37% of failures
# of failed axles with Press Tonnage below 65 tons	50	63% of failures

Of the 79 axle failures, 50 were assembled utilizing the lower tonnage specification and 29 utilizing the higher tonnage specification, representing 37% and 63% of the failures respectively as shown in Figure 2 below. There is no clear trend of the failure rate between the two press tonnage populations.

Figure 2. Failed axles by press tonnage specification



Of the 2992 axles, 50 axles assembled with the lower tonnage specification failed, representing 1.7% of the entire fleet and 29 axles assembled with the higher tonnage specification failed, representing 1.0% of the entire fleet as summarized in Table 3 and Figure 3 below.

Table 3. Summary of Axle Failures by Press Tonnage per the Fleet

	Number	Percent
Total # axles	2,992	
# of failed axles	79	2.6% of failures
# of failed axles with Press Tonnage above 65 tons	29	1.0% of failures
# of failed axles with Press Tonnage below 65 tons	50	1.7% of failures

Figure 3. Failed axles by press tonnage specification compared to the Fleet

Wheel Climb and Restraining Rail

While the original rationale for the installation of restraining rail in 8 specific locations on the mainline could not be located, a 2014 study by WMATA's track engineering services department references a number of wheel climb incidents occurring prior to April 2001. It assumes that the recommendation to add a restraining rail to curves with radii of less than 755ft and #8 turnouts was an attempt to address these incidents.

However, WMATA chose to address wheel climb through other measures, specifically by increasing the flange angle on railcars. Additionally, the curves on the mainline that have the tightest radius operate at their designed speed and already utilize restraining rail.

Metro has installed restraining rails on eight curves on the mainline, and the rationale for the selection of these locations has yet to be determined. The 2014 report addresses the issue:

> *The need for restraining rail typically involves preventing flange climb derailments or reducing excessive rail wear along the high rail. [. . .] The issue of flange climb derailments is probably not a concern because if it were, all the 755-ft radius curves would have restraining rail to prevent this type of derailment. This leaves the issue of excessive rail wear as the main reason for installing restraining rail on the 4-755-ft radius curves*

WMATA has scoped a study on the feasibility of removing the restraining rails from mainline curves. Given their complex assembly design with many bolts and studs that require constant replacement, the challenges they pose to grinding track and the limited benefits they provide, removal of the restraining rail may save track time and resources that could be more effectively spent elsewhere. The scope of work for the study is being reviewed by CENV and expected to launch in Q2 of 2023.

Inspecting Frog and Interlocking Conditions

Metro's track inspection program is in line with industry standard track inspection requirements.

Metro uses a walking track inspection of all main tracks and secondary tracks including special trackwork in an assigned section. Only employees that have successfully passed Metro's training course are qualified to be track inspectors.

All mainline tracks in an assigned section are inspected, on foot, twice a week, with at least one calendar day between inspections. Track components, such as running rail, switch points, restraining rail, fasteners, are visually inspected, and exceptions recorded on the TRST Daily Track Inspection Report and uploaded to Optram. Detailed inspections of all mainline interlockings are conducted monthly (with an interval of at least 20 calendar days) by qualified track personnel.

7-Day Inspection Interval

As stated in the Return to Service Plan, back-to-back measurements will be valid for passenger service for seven consecutive service days.

When deciding this inspection interval, CENV considered the safety of the seven-day inspection interval based on both test data and real-life data.

Data from actual operations in passenger service (Pre-derailment)

Historical real-life data shows a successful operation in passenger service for a total of 10.5 million miles accumulated from April 2015 through February 2017, prior to the first failure in March 2017. This population represents the first 290 cars accepted during Commissioning and contains both low and high tonnage cars.

Engineering Test Plan 140107

ETP 140107, also mentioned above, considered the appropriate inspection interval based on cars with varying characteristics. The 7-day inspection interval was validated with the completion of 81,824 accumulated miles on all lines in November 2021 for 15 consecutive days. The measured back-to-back data shows that no failure occurred on any wheelset (64 total). See Attachment 1

Engineering Test Plan 100002 (7K Root Cause Dynamic Test)

Analysis of the wheelset back-to-back measurements was conducted utilizing the maximum measured value (worst case) for each axle on all tested cars. The calculated average change for all axles was within the tooling and process tolerances and therefore considered statistically insignificant. See Attachments 2 and 3.

Data from actual operations in passenger service (Post-derailment)

Real-life data has also shown no statistically significant wheel migration. During phase 1 from June 16 to Sept 2nd, over 64,638 back-to-back and journal bearing gap measurements have been taken over 79 days with no wheel movement exceeding the specified tolerance in MSI 140026 Rev. 3. In Phase 2 specifically, since Oct 3rd, 30,700 measurements have been taken over 40 days with no movement exceeding the specified tolerance in MSI 140026 Rev.3.

Metro analyzed data for the first 30 days of the Return to Service Phase 2 with 941,694 accumulated mileage from September 3rd to October 2nd showing:

- Summary of back-to-back and journal bearing gap measurement data
- Operating history for each car
- Trend analysis of selected cars

There have been 2 reported failures per MSI 140026 as follows:

1. Car 7447 exceeded Specified Wheelset Limit. CENV investigated this non-compliance and concluded the failure is likely due to wheel runout.
2. Car 7365 exceeded journal bearing gap criteria. However, the axle back-to-back was within the specified wheelset limit.

<u>Attachments</u>

1) ETR 140107 Rev. 00 – 7K Wheel Back-To-Back Evaluation
2) ETP 100002 Rev. 00 – 7K Root Cause Dynamic Testing
3) Movement Analysis of ETP 100002 – 7K Root Cause Dynamic Test