MEMORANDUM

DATE:	07/30/19
TO:	Tom Prendergast
FROM:	Al Bobby and Joe Olson
SUBJECT:	Stage 1 Continuous Welded Rail Issues Related to Temperature

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Purpose:

The purpose of this memo is to present findings from review of continuous welded rail (CWR) installation reports for the Stage 1 Confederation Line Light Rail project in Ottawa, Ontario. Conclusions from data review and recommendations for mitigating potential issues based on industry best practices will also be presented.

Findings:

- Rail was laid with low neutral temperatures based on field reports in the 10° C – 20◦ C (56° F - 68° F) range
- Sun Kinks (or buckling of the track) are being reported by revenue vehicle operators based on degraded ride quality
- Contractor has cut sections of rail in the areas of sun kinks to release thermal expansion forces in track (small sections of rail removed and welded). Contractor has stated that rail sections will be reinstalled in kind during the fall season when temperatures cool to restore rail to original neutral temperature.
- Ballast condition and compaction factors into preventing sun kinks. No assessment was provided of the ballast condition on the track section. It was reported that ballast compaction was achieved through revenue vehicle and equipment train traffic over the track. No stabilizing with mechanical equipment was performed.

Conclusions:

- Hot weather conditions are causing sun kinks along Confederation Line track and are causing speed restrictions.
- Sun kinks can force track out of alignment causing a major event if not detected early and repaired.
- To mitigate sun kinks, cutting sections of rail from track will reduce thermal expansion forces causing buckling.
- Based on visual inspection, most track sections appear to have sufficient ballast. Ballast coverage and compaction is a critical component to track structure stability and maintaining proper alignment. Areas with weak or insufficient ballast section are more vulnerable to sun kinks and track buckling.

Rail Industry Research and Analysis:
The following table shows neutral rail laying temperatures for various freight and transit rail systems in North America. The neutral rail temperatures are typically 90° F or higher based on the maintenance and operating philosophy that the railroads would rather repair a rail break in colder weather than a sun kink due to track buckling in hot weather.

Rail System	Neutral Continuous Welded Rail (CWR) Laying Temperature	Source
Chicago Transit Authority (CTA)	90° F	CTA Engineering Dept
Utah Transit Authority (UTA)	Follow Union Pacific Railroad Track Standard Drawings - 90° F	UTA Commuter Rail Design Criteria Ch. 4 July 2010 Rev 2
Denver Regional Transportation District (RTD)	90° F	Denver Transit Partners Eagle Project Design Basis Manual Rev 6
Toronto GO Transit Metrolinx	100° F (37.7° C)	GO Transit Track Standards Rev 1
Waterloo Light Rail	90° F	CWR Spec
Canadian Pacific Railway Winchester Subdivision (Ontario)	90° F	Canadian Pacific Railway Red Book of Track
Canadian Pacific Railway Belleville Subdivision (Ontario)	90° F - 95° F	Canadian Pacific Railway Red Book of Track

The TCRP Report 155 Track Design Handbook for Light Rail Transit states in section 13.3.1.2.14 'De-stress and Make Closure Welds' that typical neutral rail temperatures vary by geography from anywhere between 95° F to 130° F to mitigate risk of track buckling in hot temperatures.

The handbook notes that well-built ballasted track can withstand about 187,000 pounds (~183 kilonewtons) of compressive force before buckling. To mitigate risk of track buckling, AREMA recommends a rail neutral temperature no lower than 50° F to 70° F (~- 30° C- 40° C) below the maximum expected actual rail temperature be used. Note, actual rail temperature can reach up to 40° F (22° C) above ambient air temperature.

Union Pacific Railroad (UPRR) notes in their Engineering Track Maintenance Field Handbook that a 1,440 foot section of CWR expands 9/16 inches for every five-degree (Fahrenheit) increase in temperature. For example, if a 1,440 foot string of rail was laid at 60° F and the actual rail temperature increased to 120° F, the rail will expand approximately 6.95 inches when unconstrained by fasteners.

To mitigate risk of track buckling due to high thermal expansion forces, the UPRR installs CWR at high neutral temperatures. In areas with cooler average ambient temperatures, the rule-of-thumb is to lay rail at a neutral temperature 40° F to 45° F above average annual temperature to mitigate rail breaks in cooler months.

GO Transit specifies a preferred laying temperature range of 90° F to 115° F (32.2° C—46.1° C) to mitigate track buckling during hot weather. As an added precaution, hot weather track patrols are required during summer months when ambient temperature exceeds 30° C (86° F). Remedial action is required either through speed restriction or rail adjustment when any of the following are found: Rail running through anchors, rail base lifting, canting on rail curves, gaps or voids at ends of ties indicating lateral movement of track, tie movement, etc.

Recommendations:

- Typical industry practice recommends laying rail with neutral temperatures 32° C – 46° C (90° F – 95° F) to reduce risk of sun kinks and track buckling caused by hot weather. For example, Canadian Pacific Railway subdivisions passing through Ontario near Ottawa prescribe neutral rail temperature at 90° F – 95° F. Laying rail at higher neutral temperatures reduces the magnitude of temperature change between desired rail temperature and highest actual rail temperature. Reducing the difference in net temperature change will reduce change in thermal force in hot weather.
- Readjust (destress) continuous welded rail (CWR) to increase neutral rail temperature, reduce possible thermal force due to hot weather, and reduce risk of sun kinks and track buckling.
- Inspect track on a regular basis either on foot or hi-rail vehicle with roadway workers. Typical signs of track buckling (e.g. wavy rail, line deviations, gaps or voids in ballast at end of ties, and longitudinal rail movement) can be difficult to see from a vehicle traversing track at revenue service speed.
- Typical industry practice is to implement extreme weather procedures that increase frequency of inspection and mandate speed restrictions. Suggest developing and implementing similar extreme weather procedure.
- Recommend rail cuts be made to mitigate buckling rail in hot weather conditions and do *not* reinstall rail in the cooler season, effectively increasing neutral rail temperature.
- Inspect ballast condition along corridor and add or compact as needed to ensure proper track section. Maintain ballast compaction and shoulders dimension to ensure track stability. If track ballast is disturbed, utilize mechanical stabilizer to compact and establish proper ballast shoulder. If mechanical stabilizer is not available, speed restrictions should be issued over section of disturbed track until sufficient tonnage prescribed by Engineering Department has traversed section to compact ballast.

Overview:

The contractor for Stage 1 Confederation Line laid continuous welded rail (CWR) at 10° C – 20° C or 50° F – 68° F based on De-stressing Inspection Quality Forms. This temperature is lower than the typical standard railroad practice of laying rail with neutral temperatures ranging 90° F – 100° F or higher depending on geographic location.

Based on practical railroad maintenance experience and guidelines from AREMA and TCRP 155, the neutral laying temperature or Preferred Rail Laying Temperature (PLRT) for a project should consider extreme heat and the highest rail temperature possible in project area. Factoring the highest rail temperature into the PLRT will help to prevent sun kinks (track buckling) during extreme heat conditions. For example, during a hot sunny summer day when ambient temperature is 100° F, the actual rail temperature can reach 115° F to 120° F +/-. If rail in this area was laid at a PLRT of 50° F – 60° F, the difference in temperature between PLRT and actual could be as high as 70° F creating high compressive forces due to thermal expansion. The resulting thermal forces could create a sun kink at a weak point in track section.

For comparison, Canadian freight railways and specify a PLRT of 90° F – 95° F in the subdivisions near Ottawa. Similar PLRT as used by other North American transit systems. In addition to a high PLRT, the railways also institute speed restrictions either during extreme heat conditions or if track structure has recently been disturbed (e.g. track surfacing) where ballast has not yet fully settled.

Regarding difference between freight and passenger operations, thermal expansion impacts steel rail track no matter what type of traffic is traversing a corridor. The factors that typically lead to sun kinks and track buckling are: high compressive forces due to thermal expansion and weakened track structure. Dynamic vehicle loading does increase risk of sun kinks on downgrades and horizontal curves due to increase forces to a lesser extent. Although dynamic loading of freight traffic can be higher than passenger, the main forces leading to sun kinks, specifically thermal expansion, do not change based on vehicle type.

To mitigate sun kinks on the Confederation Line this summer, the contractor reported removing small sections of rail at three locations. The sections ranged in size from 10mm (3/32") to 15mm (5/32") for a total removal of less than 1/2". This method of removing rail is consistent with our recommendation to mitigate track buckling in warmer conditions although the limited size of the removal at less than 1/2" does not seem cost effective. Additionally, the prospect of reinstalling less than 1/2" of rail in the cooler fall season not only eliminates improvement in increasing neutral rail temperature it also does not seem cost effective.

Regarding the comment on ballast settlement, although we do not have exact record of traffic on the line, it is our understanding that there have been trains running for nearly 1 year. Over the past five to six months, daily traffic has increased to 10 to 15 trains a day for testing and commissioning. The traffic over the line in the past year has sufficiently settled and compacted the ballast. In addition, we strongly recommend the use of a Dynamic Track Stabilizer in future maintenance activities.

Finally, based on the three contractor De-stressing Inspection Quality Forms from June 20th and 21st 2017, the rail was laid on the lower range of the PLRT of 10° C – 20° C at an average of 12.45° C (54.41° F). This average rail temperature is approximately 35° F below typical railroad PLRT. Because of the low neutral rail temperature, the system is at risk of requiring temporary operating speed restrictions and increased maintenance costs due to repairs of track buckling in hot weather. It is our recommendation that the Preferred Rail Laying Temperature be raised to 90◦ F based on good railroad practices presented within this report. In addition, close monitoring through inspection during hot weather events combined with good track maintenance practices will help reduce safety concerns.